VEGETATIONAL SPRAY TESTS IN SOUTH VIETNAM

APRIL 1962

U.S. ARMY CHEMICAL CORPS
BIOLOGICAL LABORATORIES
FORT DETRICK

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ABSTRACT

A variety of defoliants and vegetation killers were tested in South Vietnam to evaluate their effectiveness in denuding jungle growth. Both recognized and unidentified species of grasses, shrubs, and trees were sprayed from the air or with ground equipment. Results were recorded in color photographs. Effectiveness varied from poor to excellent. Controlling factors were limited equipment, low dosage rates, and meteorological conditions.

The work is recorded in two volumes, of which this is the first. The second, "Vegetational Spray Tests in South Vietnam, Supplement," is classified (62-FDS-834).

FOREWORD

Instructions for the preparation of this report included the requirement that only one of the two areas of effort (Task 20 and not Task 2) in Free Vietnam should be reported. This has been done; however, not all of the pertinent documents on Task 20 are available to the author, and many documents that are included contain material pertinent as well to Task 2. In order to make the record as complete as possible, all available pertinent documents have been included in the Supplement to this report, although they may refer to Task 2 as well.

Jungle, roadside, and swamp vegetation offer areas of concealment to terrorists in Free Vietnam, allowing them to establish bases hidden from aerial observation, and to ambush friendly traffic along roads and waterways. Defoliating the vegetation or killing it could improve the observation of such areas.

A satisfactory universal defoliant remains yet to be discovered. Because known chemicals have been used for several years to kill various kinds of vegetation in the US, chemicals of this type, immediately available in quantity, together with candidate defoliants or desiccants, were tested in South Vietnam to demonstrate what could be achieved on the botanically unknown species of that country.

This report concerns the work performed by the writer in South Vietnam under the auspices of OSD/ARPA during two periods, mid-July to mid-November, and mid-December 1961 to mid-February 1962. Because of the urgency that this effort be of assistance to South Vietnam, both the disseminating hardware and the chemicals had to be those immediately available. ARPA was informed before the writer went to Vietnam in July that the killing action of the chemicals to be used for aerial sprays was not particularly rapid, requiring weeks rather than days for maximum effect. They indicated that time for effect was not critical.

In regard to Task 2, the demonstrations performed in that task were immediately accepted by the VN and US alike. Both Tasks 2 and 20 were performed under the strictest security conditions. Operational personnel accordingly could have been inadequately informed on the technical requirements of these tests.

Because of the urgency associated with the preparation of this report, several people have been involved and their assistance is gratefully acknowledged:

Dr. Charles W. Beard	Mr. George A. Evans	Mr. William B. Johnson
Mr. Lester W. Boyer	Dr. Robert J. Goodlow	Dr. C. E. Minarik
Mr. Robert K. Castle	Mr. A. E. Hayward	Major James W. Startt
Colonel Carl S. Caste	Mr. Kent R. Irish	Mrs. Carolyn M. Walker

DIGEST

This report sets forth in detail the vegetational spray tests performed under the auspices of OSD/ARPA in Free Vietnam and presents illustrations of the results achieved. In the performance of these tests several aerial spray systems and a ground system for roadside sprays were utilized with varying degrees of success. These systems had not been previously calibrated for spraying the chemicals, which were not only of greater viscosity but required higher flow rates than those liquids normally sprayed by these systems for other purposes.

The chemicals used and those ultimately recommended (purple, pink, and green) for larger-scale use are plant-growth regulators known to be effective in killing many US species, including trees and brush, and are commonly used in the US for this purpose and for weed control in agriculture.

The great majority of tree species encountered in Vietnam are unknown and remain to be identified. Because species of plants are known to vary in their sensitivity to these chemicals, it was necessary to test each chemical against these unknown species and ascertain a suggested use-rate to achieve a useful killing effect. Ultimately, this was to provide increased visibility in jungle, mangrove, or roadside areas.

For greatest and most rapid effect, vegetation should be in a stage of active growth. Good coverage, including penetration of the foliage with sufficient chemical, is mandatory. Under these conditions, it is estimated that two to six or eight weeks are required for the death of susceptible species, depending upon their sensitivity, and that generally 70 per cent or more of the forest stands at the various test sites are capable of response.

Most aerial releases were performed with the C-47 spray rig, which was the only aerial system available for an extended period. Unfortunately, it was the least suitable system; it consistently failed to achieve sufficient flow rates and deposited sublethal amounts of the chemicals even though it was functioned at maximum pressure. This pressure probably made the spectrum of particle sizes in the spray smaller than desired and under lapse or neutral atmospheric conditions could have contributed to excessive spray dissipation. An unequivocally successful test with this equipment at tree-top level under inversion conditions near the Bien a airstrip in October substantiated the equipment limitation and confirmed chemical effectiveness. With relatively minor re-engineering, it is believed that this system could be satisfactorily improved for this spray purpose.

These tests were performed under conditions of great security consonant with VN requests and US agreement, and information concerning them was disseminated on a very strict need-to-know basis. Later, when large-scale

operational testing was initiated and conducted by USAF, too few people were cognizant of all technical requirements. Those that were cognizant could be heard only incompletely or lacked authority for insuring technical compliance.

The equipment used in the USAF tests was used for the first time for spraying chemicals to kill vegetation. There was insufficient time to get the equipment checked out for spraying these chemicals and needed adjustments were made on the basis of the results of spraying the first USAF targets on 13 January 1962. Complete calibration of the equipment for spraying these chemicals is essential for the most efficient effect.

The majority of the aerial spray tests were performed during the period August to October, 1961. The results obtained varied from relatively poor to very good. In this period the least impressive results were associated with equipment limitations rather than with a lack of vegetation response to the chemicals. Unfortunately, the USAF spraying did not get under way until the middle of the dry season, which in upland areas markedly curtails active growth, a condition preventing expression of the chemical effects.* In mangrove areas, where water was plentiful for growth, visibility was markedly improved in one month's time.

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* NOTE: A message from COMUSMAC Vietnam to CINCPAC dated 23 March 1962 demonstrates the efficacy of the USAF tests in spite of the technical problems encountered. The text of the message is published as Section I of the Vegetational Spray Tests Supplement (62-FDS-834).

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1. BACKGROUND

A. TECHNICAL PROBLEMS

On approximately 10 days' notice, the author went to South Vietnam to conduct tests in connection with Tasks 2 and 20, which were already set up in the joint program of the MAG R&D Division and the VN Combat Development Test Center (CDTC). For these tasks the assistance of Mr. W. B. Johnson was requested for the initial phases of the work, and that of Mr. L. W. Boyer for the latter phases. The time periods on location for each of the above were:

	Arrived	Departed
J. W. Brown	17 July 1961	14 November 1961
	14 December 1961	16 February 1962
W. B. Johnson	17 July 1961	12 September 1961
L. W. Boyer	10 October 1961	2 February 1962

At the outset, demonstrations were to be performed with chemicals and spray equipment immediately available and time for effect of the chemical spray was indicated to the writer as not being critical.

U.S. military research in defoliation has been unfunded since FY 1958. Therefore, although today there are chemicals of promise in causing defoliation, the urgency of the situation in Vietnam practically dictated our using only those chemicals for test that had had considerable research, proven performance, and practical background. Also, other factors had to be considered, such as availability in large quantity, costs, and known or proven safety in regard to their toxicity to humans and animals if a scale-up of spray use should be required. The chemicals selected for test should be considered not necessarily as "defoliants" but as vegetation control chemicals that are effective in killing susceptible species. Additionally, it was believed that killing the vegetation would achieve a more lasting effect. See Section II of the Vegetational Spray Tests Supplement (62-FDS-834).

In general, all the available spray equipment had been designed primarily for spraying chemicals or materials with physical characteristics including lower viscosity) different from the test chemicals. Moreover, the equipment had to be assembled on location and tested functionally prior to spraying chemicals that had been selected for vegetational tests. For the assembly, installation, and functional testing of a 675-gallon C-47 spray rig, a 90-gallon 1-B spray tank mounted on an AD6, and a 200-gallon Helicopter Aerial Dispersing Apparatus Liquid (HIDAL) mounted in and on an H 34, the assistance of the following specialists was essential:

Sgt. James McIntosh, USMC Ser. #1458 145894 MOS 6511
T/Sgt. Leon O. Roe, USAF, AF 6969313

Another piece of equipment, a 100-gallon "Buffalo Turbine," was also assembled and functioned. This equipment is mounted on a single axle and can be towed for ground operation, or it can be loaded onto and functioned from a 2½-ton truck bed. The HIDAL was functioned first on 10 August, the C-47 on 24 August, and the 14B on 25 August, all using Dinoxol, a commercial preparation of 2,4-D and 2,4,5-T growth-regulator vegetation killers. The Buffalo Turbine was functioned with Dinoxol on 18 September.

It was originally intended to provide the Vietnamese (VN) with a spray capability with the C-47 spray rig and with the Buffalo Turbine; the other units were to be only for loan or demonstration (See Section III of the Supplement). It was essential for VN pilots to be instructed in aerial spray techniques if they were to fly C-47 spray missions. To provide this instruction, Captain Mario D. Cadori, USAF AO 936686, was assigned on TDY, but only after the writer refused to take the responsibility for the safety of the VN flyers and the equipment if they were denied this instruction. This special kind of flying is beyond doubt hazardous, and Capt. Cadori accomplished a very difficult task of instruction in an outstanding manner.

Unfortunately, high hopes were placed on the usefulness of the C-47 spray equipment because it had the greatest capacity and it was used for most of the test spray releases. However, the spray results using this rig were the least impressive of any of the aerial systems employed. Section IV of the Supplement to this report discusses the shortcomings of the C-47 spray system. Yet it was the only system available for conducting the subsequent aerial tests, because after the H-34 test spray of 10 August using the HIDAL, this system was grounded (in the US as well) until a "fix" was available and was not functional again until 12 January 1962. The 14B/AD6 system was dismantled and returned to the USMC according to plan after its demonstration flight. The C-47 system should not be condemned wholly, for it is believed that with relatively minor re-engineering it could be adapted for spraying these more viscous materials. It appears that first steps to improve its use for this purpose would include more suitable nozzles, a pump of greater capacity, and piping to allow greater flow rates with less pressure drop. The inclusion of a flow meter in the system is desirable where solutions of different viscosities are to be sprayed. It is not known, however, whether the facilities and materials in Vietnam are adequate to accomplish these steps, simple though they may sound. Capt. Frank Dowell, USAF, 2nd ADVON, is the best authority on the necessary changes to this equipment, including the requirement for calibration of the altered equipment. The latter requirement applies also to the C-123 equipment, that is, it also needs calibration.

Because it takes two to six weeks or more for peak effectiveness to show as a result of spraying these chemicals, and the time required is dependent on several factors, the deficiencies of the use of the C-47 rig were not readily apparent. In the minds of many, the chemical effectiveness

was suspect. There were, however, successful tests with the HIDAL (Test 1), the 14F (Test 3), and the Buffalo Turbine (Test 9), which indicated that the use of the C-47 rig (Tests 2, 4, 5, and 6) left something to be desired.

Several factors came to light on examining the C-47 rig and its history:

(a) The system had been designed to spray insecticide solutions of lesser viscosity than that of either Dinoxol or Trinoxol, which were of about similar viscosities.

(b) For normal use of the system in the US, a deposition rate of about 1/3 of a gallon per acre is desired, whereas, with the vegetation killers at least 3 times this amount was sought.

(c) For its normal use in the US, a mass median particle diameter of about 65 microns is useful in area coverage work where aimability of the spray is not a stringent requirement. For vegetation killers a spectrum of particle sizes ranging from about 50 to 250 microns was sought, but it was necessary to use the nozzles originally selected for spraying insecticide.

(d) In its normal use in the US, an effective swath of about 300 feet was assumed, and this swath was assumed for the spray of vegetation killers.

(e) Because of factors beyond control, the sprays were not always released under inversion conditions.

(f) Efforts to obtain increased flow rates to satisfy (b) above apparently aggravated the situation, because particle sizes already small were made smaller, so that dissipation of the spray was increased, especially if the release was not made under inversion conditions.

As a result of this examination, it was concluded that sufficient chemical was not being deposited on the test vegetation with this equipment.

An effort was made to confirm this finding by the three swaths that were sprayed near the Bien Hoa Airport on 17 October. The pump pressure was maximum (30 psi vs 20 psi); the altitude of release was requested at 25 feet (intended to be above the tree tops, but the VN pilot misunderstood and clipped tree tops with the propellers); the most appropriate chemical left in sufficient quantity at this time, Trinoxol, was used; the spraying was done under inversion conditions at about 0845 in the morning, the easternmost swath was sprayed twice to achieve a double dose. Photographs (Test 7) show the spray delivery and lasting effect. There is little evidence that the swath that was sprayed twice showed more effect than those with a single spray. It is possible that regrowth may not occur as rapidly in this swath, but all swaths appeared about the same three months later without obvious regrowth. (In the photographs, the green vegetation

apparent in the center of each swath is the unsprayed area that was directly below the fuselage of the C-47 when it was spraying at the very low altitude. The spray booms and nozzles are located under each wing of the C-47.)

The test site near Chon Thanh was a roadside site that was the first sprayed with Dinoxol by the C-47 rig on 24 August. It was planned to spray by 0900 hours, but difficulties and delays encountered by the ground party in driving to the site delayed the spraying until 1030, with a consequent loss of inversion conditions. The modest security guard was increased en route to about 60 armed soldiers and 6 armored cars as we neared the site. It was learned later that a VC (enemy) ambush had occurred two days prior to spraying at the very kilometer marker (No. 76) used for one end of the test runs. The concrete marker itself had been moved by the VC to the middle of the road to block traffic, and foxholes were evident on either side of the road. This site was four kilometers long on both sides of the road, 76 to 80 kilometers almost due north from Saigon. This test site was selected personally by President Diem. Reports from the Kontum area, where successful roadside sprays with HIDAL were performed 10 August, may have been available to him, but this is not known to the writer.

B. WORKING CONDITIONS

With the relatively short notice available for the trip to Vietnam, but little indoctrination was possible and consisted in the main of quickly reading "The Ugly American" and attending for one afternoon two scheduled presentations at the Military Assistance Institute. Perhaps this was adequate under the circumstances, since there was precious little time to grasp even the rudiments of the language. The language difficulty was most apparent initially, and it is suggested that anyone who takes the trouble to learn some Vietnamese and use it will receive the respect of the VN perhaps somewhat sooner than he ordinarily would. They accept this as a high compliment and a rarity, for so few Americans speak their language.

In a MAAG brochure for those assigned to Vietnam there appears the following well-written and meaningful paragraph:

"YOU AND VIETNAMESE PUBLIC OPINION. The over-all opinion of United States held by the people of foreign lands is of tremendous importance to our country, our nation's objectives, and the future of the Free World. This opinion is developed primarily, not by government directives or announcements, but by individual impressions gained by these people through their contacts with individual Americans. Therefore, you, and all other Americans who come to Vietnam, play a most important part in the furthering of our national interest, over and above the official tasks you perform, simply through your day-to-day contact with the Vietnamese. You will find them friendly and courteous, interesting and congenial, and you will probably

makes some very fine friends during your stay in Vietnam. It is hoped that you will go more than half way in developing these friendships and that in your contacts with the Vietnamese people you will be guided by the realization that common decency, patience, understanding, politeness and sincerity are qualities appreciated the world over. A smile means the same thing in all languages."

In regard to the above paragraph, it is in a sense regrettable that such a paragraph was deemed necessary in the first place. In the second place, if it was read, it very apparently was not only easily ignored, but individual behavior was obviously contrary to its message. In the third place, those who attached importance to its content and made an honest effort to comply with its intent were often held in suspicion, which on occasion approached ridicule and contempt, by those in the second category.

The Vietnamese have a respect for age, corpulence, higher education, intelligence, sincerity, friendship, and "face" that seems incomprehensible to many Americans, but this is their way of life. Those Americans in VN having any of these qualities, attributes, or characteristics have that much in their favor to establish good relationships with the VN with whom they work. However, if a sincere effort is not made or, conversely, little or no respect is shown the VN, there suddenly becomes little or no workable relationship. It appears that good relationships, mutual respect, and understanding have to be established first before real progress in the job can be achieved, but once this contact has been made and continually strengthened, the progress accelerates rapidly.

It is noteworthy that the VN refer frequently to their "friends" but rarely mention "enemies" as such - they are just not-friends, and among the VN a friend is one of whom drastic demands can be made, frequently on short notice, with the complacent knowledge that the matter is in good hands and will be handled as expeditiously and completely as possible under the circumstances. If it is not, it is understood and accepted that it was not possible. The title of "friend" conferred on anyone by the VN thus carries a connotation that is not immediately apparent to Americans, even though it may seem the word is used rather freely by them. These strong friendship ties seemingly exist throughout the VN military structure and in instances are a most expeditious means of fulfilling urgent, legitimate demands, requests and the like within hours or days via telephone whereas weeks or months would be required through ordinary channels. Or a paper request may be "lost" if it requires the concurrence of one who is not a friend - again a way of life perhaps developed to a high degree in the interest of necessity while the French dominated the military system.

When the writer arrived in Vietnam in mid-July with Mr. Johnson there were some 60-odd projects or tasks already in the joint program of the R&D Division (US) and Combat Development Test Center (CDTC-VN) that had been initiated in June 1961. Two of these tasks were pertinent to the writer's field of endeavor, and he was to function as the US Advisor for these tasks.

It has been requested, however, that this report concern only Task 20. At that time about three or four other tasks were activated or about to be. The R&D Division in mid-July consisted of five people, four officers and one enlisted man. The facilities were two small adjoining rooms, two office desks, two office tables, five chairs, a typewriter, two telephones, a file safe, and a big program.

A VN Colonel (Colonel Trach) had been assigned as Chief of the CDTC and two VN Captains (Captains Khoat and Chan) were on loan to him. There was no facility assigned as yet to the CDTC. The Colonel spoke Vietnamese, French, and, thirdly, English. Captain Khoat spoke Vietnamese, French, and English rather well, and served on many occasions as an interpreter. He was on loan from VN J-3. Captain Chan was on loan from Ordnance. He spoke Vietnamese and French very fluently, having studies for six or seven years in France, where he obtained a Master's degree in Chemical Engineering. He understood English if it was spoken slowly and clearly but hesitated to try speaking English for about the first ten days to two weeks of our acquaintance.

That the work reported was accomplished at all is due largely to the high level of cooperation and support supplied by the Vietnamese. Colonel Trach and his staff of Captains Khoat and Chan gave immediate attention to the problems and arrangements necessary for the execution of the tests. Captain Chan was the VN project officer for the work and did an outstanding job in helping to expedite its completion. Later, Captain Ton was assigned to assist Captain Chan and many difficult arrangements were performed by him. In instances where neither of these captains was immediately available, Captain Khoat was always helpful in attending to the requirements of the assignment.

These officers always showed the inherent friendliness of the Vietnamese toward me. Communication was not always easy in the early stages of our relationships because of my inability to speak languages better known to them. Also, their inherent politeness toward a "guest" of their government made it difficult to know the extent of understanding achieved, especially when they would tend to say "Yes" to everything the "guest" said. The writer was acutely aware of having to speak with them in English and appreciative that this was perhaps the least fluent language of the several they spoke. This was made known to them very early in our acquaintance, along with the importance of understanding, and they were invited to ask questions or have me explain as slowly, clearly, or thoroughly as they desired until the subject at issue was understood beyond doubt. It was useful several times to write out key words to clear up misunderstood pronunciation.

The very great interest shown by the VN in our work contrasted strangely with that shown by the US side in Vietnam as I saw it, especially in the July-September period. In fairness, the R&D Division was sorely overworked and undermanned to handle administrative matters alone, and those assigned to R&D tasks had their hands full with problems of their own. Also, the VN

requested utmost security (See Section V of the Supplement) in our work. The result was that, when the time came to consider expansion of the effort, very few people outside of the MAAG R&D Division were really informed of the complexities and requirements involved. Of course, monthly reports, progress reports, trip reports, and memoranda were available to provide background information to those having a need to know (several of these are not now available for use in preparing this report). The breadth of dissemination of this information is not known, because information has a way under these circumstances of travelling vertically with little lateral spread.

Another obvious difficulty was that only a very few who had some knowledge of various botanical sciences could appreciate the information available. In this particular field the entire Department of Defense had only two scientists considered qualified to tackle these problems, Dr. Minarik and me, both from the same office. So the source of the information in Vietnam was one person, and in its progression through channels oral information could have suffered considerable misinterpretation in relatively short order. As others came into the picture, they too may have had to supply information on short notice. In the latter phases (during December to February) it is possible that several sources were supplying opinions with little relation to fact, thus leading to a state of confusion. A simple point, such as time for effect to reach a maximum after spray deposition was difficult for many to understand and led to prejudgment and condemnation after a single premature observation. Another case, reduced to its simplest terms, was the assumption by others that, because the aircraft had released the spray, a lack of response justified an automatic condemnation of the chemical, ignoring the fact that a sublethal deposit had resulted that could have been due to any <u>one</u> of several things, such as excessive altitude and airspeed of the aircraft, inadequate flow rate (which was maximum for the system), lack of inversion conditions causing spray dissipation, or insufficient canopy penetration due to improper particle size and the fact that the equipment had never been calibrated with the liquids being sprayed. The assumption was inherent that <u>all</u> experiments must be successful—an odd approach to research, to say the least. That three of the first four tests with <u>different</u> equipment were considered successful (Tests 1, 3, and 9; Test 2 was the exception) was almost ignored by those who chose to concentrate on the results of Test 2 and subsequent inadequate tests with the C-47 equipment, the performance of which left much to be desired.

Consider for a moment a system, two identical buckets with a nail hole the same size in the bottom of each. Fill one with kerosene and the other with the same volume of a more viscous liquid such as S.A.E. 30 engine oil (or even liquid glue, to make the point). Which will drain first? This is essentially the viscosity problem encountered with the C-47 spray rig in trying to obtain a flow rate to give adequate deposition.

In regard to the "atmosphere" surrounding this work, the following extract is deemed appropriate. It is particularly noteworthy that it is of Russian origin.

Extract from DAILY REPORT, USSR & East Europe, 6 March 1962
No. 45 -- 1962

DOGMATISM IN RESEARCH METHODS SCORED

Moscow LITERARY GAZETTE 24 February 1962--A

(Article by Prof. V. V. Parin, member of the Soviet Academy of Medical Sciences: "The Authority of Facts")

(Summary) Never in the whole history of science has there been such a period of tumultuous development as now. The traditional concepts of the world are breaking down under the impact of new theories, and it is a single generation of men that has to digest all the changes. To some people, however, the nullification of views cherished for many years comes as a fearful shock. They had been admitting a single scientific approach and corroborating it not with the results of their own experiments, but with quotations from the works of predecessors. In this lay the chief harm of the personality cult in the sphere of science: that one particular school of thought was held to be the sole receptacle of truth. Yet such a slavish inertia is contrary to the spirit of dialectic materialism, which admits no such bounds to knowledge.

. . . . . .

I have dealt in some detail with the position in physiology and in medicine. However, the problem of the struggle against dogmatism, of a proper approach to the scientific heritage, of keeping up a healthy and genuinely creative atmosphere, is not a physiological or biological problem; it is a general one. It should agitate and it does agitate people working in various spheres of the natural, precise, technological sciences as well as the humanities.

The time is coming when the young generation which we ourselves are educating will take our place. But to teach people the methods of experimental work, of mathematical calculations, and of analyzing the facts gathered is only half the task. Thinking methods which we must inculcate in our pupils must be based on high ethical principles. Genuine science boldly advances into the uncharted fields, constantly developing the tools and methods of research. It never hides behind the authority of great leaders of either today or tomorrow. The truth is always born in a struggle of opinions, in hot creative debates.

> For the sake of the truth, a scientist must be able to drop his own views, no matter at what cost they have been acquired. They must not be stayed by force or by administrative influence, for in this case, a personal collision threatens to grow into a social one. Science breathes only one kind of air—the oxygen of facts. New research methods are the trees cleansing the atmosphere of the carbon dioxide of newly revealed, realized, and understood phenomena. A healthy atmosphere is incredibly important to science. It is not in vain that the greatest of the documents of the epoch in which we are living explicitly refers to this creative atmosphere.

Because the above was written for Russian consumption, the writer suggests a rewrite for the first two sentences of the last paragraph:

"For the sake of the truth, a scientist must be able to change his own views, regardless of the consequences. He must not be swayed by force or by administrative influence, for in this case, a personal collision threatens to grow into a social one." The statement: "A healthy atmosphere is incredibly important to science" bears repeating for the consideration of those administering programs of science. It is difficult enough to search out the truth and advance science even in a free atmosphere uncluttered by preconceptions, misconceptions, misunderstandings, and misrepresentations by others.

II. CHEMICALS FOR TEST

Many factors were involved in the use of chemicals in this instance. Only certain chemicals were immediately available in quantity to be operationally useful in defoliating or killing jungle vegetation. The country is actively fighting communist aggression where the jungle foliage is used by the enemy to conceal their bases and to ambush traffic along roads and waterways. There is an urgent need to suppress communist terrorism. The standards of living of much of the population may be classed as primitive. Under these conditions, requirements in addition to effectiveness of the chemicals on vegetation include:

(a) The chemicals must be nontoxic to humans in handling, in exposure to dissemination by air or ground equipment (either by direct contact or by the respiratory route), or in the consumption of edible produce.

(b) The chemicals be compatible with the equipment for dissemination, i.e., noncorrosive, noninflammable, etc.

(c) The chemicals have physical characteristics that allow them to be disseminated by available equipment so that sufficient quantity can be deposited on the vegetation without undue dissipation or evaporation. In addition, they must present no unusual or difficult storage, handling, or mixing problems; these include crystallizing at temperatures likely to be encountered in storage or in flight, leaving residues to clog a spray system, or exceeding the facilities available for any mixing required.

(d) The use rate should be as low as possible for effect.

(e) The cost should not be prohibitive.

Allowing for the above criteria, commercial concentrates of 2,4-D and 2,4,5-T were used to provide demonstrations of effect (Table I).

This approach was considered to provide the most direct route to operational usefulness and aid to the Vietnamese consistent with the prevailing urgency. These chemicals have been known and used in the US for more than 15 years, are considered safe to animals and humans, and otherwise meet the requirements above. Additionally, in 1959 chemicals of this type were used successfully to kill the trees growing in an area of about four square miles in an impact zone at Camp Drum, New York. Section VI of the Supplement is a summary report of the work at Camp Drum.

Another approach could have been micro-testing on small plots with numerous candidate chemicals that had far less background for meeting all the requirements. Sixteen of these candidate chemicals were on hand in quantities ranging from grams to gallons. Costs, lead times for quantity

TABLE I. CHEMICALS TESTED

Color Code	Chemical	Commercial Name	Quantity	Received	Disposition
-	20% 2,4-D butoxy ethanol ester 20% 2,4,5-T butoxy ethanol ester	Dinoxol	500 gallons	17 July 61	Exhausted 12 Jan 62
-	40% 2,4,5-T butoxy ethanol ester	Trinoxol	535 gallons	4 Sep 61	Used 385 gallons; 150 gallons to VN Jan 62
-	30% 2,4-D ethyl ester (water formulation)	Conc. 48	500 gallons	4 Sep 61	Used 100 gallons; 400 gallons to VN
Pink	60% isobutyl ester 2,4,5-T 40% butyl ester 2,4,5-T	-	- -	20 Nov 61 9 Jan 62	-
Green	100% butyl ester 2,4,5-T	-	-	20 Nov 61	-
Purple	50% butyl ester 2,4-D 30% isobutyl ester 2,4,5-T 20% butyl ester 2,4,5-T	-	-	partial shipment 9 Jan 62	-
Blue	65% cacodylic acid	Ansar	-	20 Nov 61	-

production, and human and animal toxicities for most of these candidate chemicals were unknown, and any one of these factors could have limited or delayed active help to Vietnam. In any case, it is extremely doubtful that anyone could have been convinced of the real worth of a chemical as a result of testing only a few grams or even a few gallons. With these limited quantities, only a small number of the array of unknown species of vegetation could have been tested. It is not intended in any way to minimize the importance of such testing, but rather to put it in perspective in relation to the combined "research - aid to Vietnam" objectives. Thus, these candidates were tested in the latter part of December and in January, whereas the major aerial testing of the 2,4-D and 2,4,5-T chemicals was conducted from August to October. The chronology of tests, equipment, chemicals, and observation dates are listed in Section VII of the Supplement.

Actual figures on viscosities were not available until 17 April 1962 because the necessary equipment was not at hand. Table II shows both absolute and relative viscosities for the purple, pink, and pink-green chemicals.

TABLE II. VISCOSITIES OF CHEMICALS COMPARED WITH WATER[a/]

Temperature °C	Temperature °F	Water	Purple	Pink	Pink-Green[b/]
		Absolute Viscosity, centipoises			
38	100.4	0.6814	590.5	1028	1319
32	89.6	0.7679	1115	2076	2650
28	82.4	0.8360	1688	3450	4270
23	73.4	0.9354	2981	6522	7562
19	66.2	1.0299	4768	11370	12930
14	57.2	1.1709	8441	22494	30160
		Viscosity Relative to Water			
38	100.4		853.7	1508	1934
32	89.6		1452	2703	3451
28	82.4		2091	4126	5108
23	73.4		3187	6972	8084
19	66.2		4630	11040	12550
14	57.2		7209	19210	25760

a. Prepared by Ralph E. Buschmann.
b. 1:1 mixture by volume.

III. EQUIPMENT

A. VARIATIONS

Inherent differences in various aerial vehicles for delivering sprays affect the deposition of the spray. Helicopter rotors provide a downward blast on the spray that can cause a desirable spray turbulence within a forest canopy, depending on the height above the trees from which the spray release is made. Section VIII of the Supplement describes the effect of spraying forests from a helicopter.

Releases from fixed-wing aircraft are in the main dependent on settling of the spray. The turbulence created by the propellers causes the spray from each boom to spiral out behind the aircraft to give the impression, under otherwise quiescent conditions, of two horizontal cylindrical clouds floating in the air. However, if conditions are not quiescent and an inversion does not exist, the spiraling effect fr the propellers seems to aid in the upward dispersion of the spray; the fine particles so impelled have little tendency to settle but are dissipated, a[illegible]ability is thereby lost, and desired deposition rates are not achieved.

The H-34, C-47, and C-123's all had split booms; that is, essentially two separate booms are operated, one on each side of the fuselage. Thus, at very low altitudes the two cylinders of spray may enter the foliage before coalescing, leaving unsprayed foliage, under the fuselage. At higher release altitudes the sprays have an opportunity to coalesce and even out the spray deposit if the conditions for settling are present.

To my best knowledge, planned flow rates, altitudes, and airspeeds for various swath widths were made to match the deposition rates desired. Thus, the amount of chemical deposited was limited and the evenness and rate of deposition were dependent on factors discussed above. Within a given swath (and especially with a crosswind release) the spray will deposit with the larger particles impacting first and the finer particles being carried farther downwind. Obviously, at some point downwind the quantity of chemical deposited tapers off and the amount becomes sublethal.

It is customary in spray work to use area as a parameter, which usually does not take into account the leaf surface of vegetation contained in that area. There can be considerable variation in the area of leaves contained on a given unit of land, depending on whether the vegetation is grass, corn, or jungle. There is no quick, easy, or exact method of allowing for total leaf surface. The rates of deposition sought in these tests and the flow rates calculated to provide them were, therefore, quite arbitrary but were guided by results achieved spraying about four square miles of forest at Camp Drum, New York, in 1959 (See Section VI of the Supplement for details.)

B. INSTALLATION AND OPERATION

1. C-47 Spray Equipment

a. Description

The equipment installed and used in a VN C-47 aircraft had been used for several years by a USAF Insect Control Group at Langley Air Force Base. The tank had a capacity of 675 gallons and was formerly used in a B-26 as a bomb-bay fuel tank for increasing range. The tank size is approximately 3 feet by 3 feet by 11 feet. A 3-inch filler pipe and vent pipe extends upward and to the outside of the fuselage.

Connected to the rear of the tank is a Marlow self-priming centrifugal pump (Model 2B2, 200-gpm output) driven by an air-cooled 5-hp Wisconsin engine. A 2-inch discharge line runs from the pump to a T connection. One line from the T runs through a valve and hence into the tank. The other line runs through a valve to the outside of the fuselage at the bottom of the aircraft and hence to a Y to connect to the left and right booms. The two valves are actuated by remote control from the cockpit. When one valve closes the other opens simultaneously. The pressure from the pump can be regulated only by pump and engine speed. No pressure regulator is incorporated into the system. The pump engine is started and the speed set manually. A quick-dump valve is incorporated as a safety feature.

The left and right booms are 1½-inch (outside diameter) pipe and each has an effective length of 18½ feet. They are mounted on wing braces and extend 22 inches below the lower wing surface. The two inboard ends of the booms are 36 feet apart. Each boom has outlets for 22 nozzles, a total of 44.

The nozzles used were Spraying Systems B-10 Whirljet nozzles with diaphragm check valves. The orifice is 3/16 inch in diameter and forms a hollow cone pattern of 72 degrees when operated in a static spray test at 20 psi (1.7 gpm with water).

Some minor difficulties were encountered during the installation of the equipment. The C-47 the VN were using was an older model than the US C-47 from which the spray equipment had been removed. Some changes were necessary in the wiring between the pilot's control panel and the spray-valve actuating mechanism. Other changes in fittings were insignificant.

b. Tests

Because of the urgency of the situation in Vietnam there was not time to conduct tests in the US with the C-47 and the liquid chemicals to be sprayed. Tests to determine particle mass median diameter (MMD), flow rate, and per cent recovery (mass deposit) of the chemical to be used in VN would have been highly desirable. Estimated dosage rates of the chemicals to kill large trees of unknown species are about five to ten pounds per acre.

Previous tests with similar spray equipment and chemicals in the US have had as their objective a small particle diameter and uniform large-area coverage at deposit rates of one pound per acre and less. This application rate is sufficient to kill many economic food and fiber crops.

Some spray deposit tests were conducted during April 1953 at Beltsville Maryland with the C-47 and the spray equipment described above. The liquid spray material was DDT and fuel oil, which is much less viscous than the solutions used in VN. The recovery ranged from 59 to 86 per cent for the six test runs conducted. The highest recovery was obtained from the test conducted under good inversion conditions. The MMD of the particles was 165 microns.

The C-47 spray equipment did not give the desired or anticipated effect at Chon Thanh (Test 2). Several factors are responsible: the pumping system failed to provide the pressure required for the desired flow rate. The amount of pressure drop in the lines from the pump to the nozzles is not known. The pressure at the pump registered 30 psi (the maximum) but at the discharge nozzles it may have been considerably less.

c. Operational Difficulties

Considerable delay was encountered in getting to the test site on the ground because of late arrival of equipment and of security clearance to work in the area. Thus, the spray run was not started until 1030 hours, when the meteorological conditions were neutral or lapse. Hence, most of the smaller droplets may have drifted off the target. The wind direction angled off the target by 10 degrees, and red indicator cards showed considerable drift of the spray off the intended target.

2. 14B Spray Tank

The 14B was designed to carry chemical or biological material externally on light piston- or jet-engined aircraft.

Two 14B tanks arrived in Saigon from Iwo Kuni, Japan, on 1 August 1961. The two units had apparently been in storage for some time. They were corroded, wires were misplaced or missing, and a few parts malfunctioned. USMC Sgt. McIntosh displayed much ingenuity in his efforts to get the units functional. By rewiring, interchanging, and repair of parts one unit was made operational.

Each unit has three major components: the nose section containing the high-pressure compressed air tank and control assembly; the center section containing the liquid reservoir (90-gallon capacity); and the tail section containing the discharge valve and control assembly.

Operation of the units is controlled from the pilot's control panel in the cockpit. Three different flow rates can be selected during flight. However, for a flow rate other than those present, the central microswitch in the tail assembly can be adjusted and reset for any of several flow rates.

When the unit is functioned, air is fed from the air tank into the center section (liquid reservoir) at 100 psi and liquid and air are then directed out and around the spear valve and diffusion cone into the airstream.

The unit was mounted on a VN AD6 aircraft and functioned perfectly. Particle MMD is estimated to have been about 290 microns. Previous tests with the 145 revealed an MMD of 272 microns at 180 knots airspeed, 173 microns at 360 knots, and 107 microns at 550 knots.

3. H-34 and HIDAL Spray Equipment

This equipment was designed and fabricated by the US Navy for use on rotor-winged aircraft to spray insecticides. It consists of a 200-gallon cylindrical tank located in the cabin. A 25-gpm electric pump, located at the bottom of the tank, transfers the liquid from the tank to the booms, which extend about 25 feet out and slightly to the rear of the fuselage in a delta design.

Each boom was equipped with 21 Spraying Systems T-jet nozzles. Each nozzle had an orifice diameter of 0.062 inch and delivered 0.6 gpm of water at 40 psi pump pressure.

Some malfunctions were encountered during the installation and operation of the equipment. A leak developed at the bottom of the tank at the outlet to the pump. A brass elbow threaded into a nylon or plastic plate did not provide a substantial seal. The plate was replaced with one made of brass. The carbon vanes in the rotary vane pump broke after a short time. They were replaced with vanes fabricated of nylon. The upper forward boom brace mounting cracked the fuselage of the aircraft and the HIDAL system was grounded for several months. A bracing cable was installed in late December to connect the left mount with the right mount inside the fuselage.

4. Buffalo Turbine Sprayer

This is a ground-operated spray rig that can be towed behind a vehicle or mounted in the bed of a pick-up or larger truck.

A 36-hp Wisconsin engine drives the turbine and the nylon roller-type pump. The turbine delivers up to 14,000 cfm, the pump capacity is one half to 30 gallons per minute at pressures up to 150 psi. A stainless steel tank (100-gallon capacity) is used for the liquid reservoir.

In operation the liquid is pumped from the tank through a pressure-relief valve and into the small boom containing four liquid nozzles. The boom and nozzles are located inside a fishtail air nozzle attached to the exhaust end of the air turbine. The high-velocity air stream breaks up the liquid and carries the particles some distance away.

The particle MMD is said to be 75 to 80 microns. Although the particles are much smaller than those from aerial releases, the effect of meteorological conditions on deposition is much less. The particles are released at ground level and are impacted on the foliage rather than being wholly dependent on inversion conditions for sedimentation.

IV. TESTS

A. PERFORMANCE STANDARDS

From 10 August to the end of 1961 all chemical tests in which the materials were released from aircraft were performed with chemicals of the 2,4-D or 2,4,5-T type. These are well-known plant growth regulators or vegetation control chemicals that have gained wide recognition and use in the United States for killing vegetation.

A very important point is that, no matter what chemicals were to be tested, they were to be tested as soon as possible, with the possibility of being used on a wide scale to aid Vietnam. Therefore, a host of other factors had to be satisfied as well; otherwise, any one of the following factors could have prevented their use. Some of the more obvious factors were availability, cost, and safety to humans under conditions of spray and handling.

Ratings in these tests were recorded by adjectives and/or estimated percentages of effect as the situation allowed, bearing in mind the following factors:

(a) Is the evidence sufficient to indicate that the chemical has in fact been reasonably well deposited on the vegetation? Better effect can be achieved on a susceptible tree if all its leaves receive a few drops of chemical as opposed to only one side or only the very top of the tree receiving all the chemical. In this connection, forms of the chemical known as volatile esters were requested subsequently in order to achieve more uniform coverage within a forest canopy.

(b) Is the vegetation in a stage of growth capable of responding? Actively growing (not dormant) vegetation responds more quickly and thoroughly to these chemicals, whereas dormant plants can usually respond only when they re-enter a state of active growth.

(c) Are the species encountered (although unknown) susceptible to the chemical? Even the Soviets are having difficulty with the unknown species in North Vietnam, and they are free to roam the country (see reference JPRS: 11373 dated 29 November 1961) as indicated by the following excerpt. The title of this paper is "Soviet Botanists in Vietnam" by A. L. Takhtadchyan.

> "As we had already known, in the democratic republic of Vietnam there are yet no botanical institutions capable of organizing or coordinating this study of the plant world of the country. Botanical research is performed mainly by the chairs of various colleges and universities; however, with the exception of a textbook on the Taxonomy written by the head of the Department of Botany of the Pedagogical Institute, Le Kha Ke, unfortunately there are no reference books in Vietnamese on botany in general or on the vegetable

kingdom of Vietnam in particular. There is no good herbarium either. Therefore, identification of plants in Vietnam presents great difficulties, and as a result, many important trees providing valuable wood, and also a relatively large number of medicinal plants have not been accurately identified until the present time."

(Additionally, the writer took a special trip to Singapore from September 28 to October 3 in order to consult with Dr. Abbe, a visiting professor from the University of Minnesota who was in Southeast Asia on a Fulbright Grant. He had, he told me, a team of three collecting forest species in South Vietnam and in six months' time this team made 14,000 collections. He estimated perhaps 50 of these collections could be identified as to genus only. The rest of the collection, he indicated, would take several years to identify and all of his samples were dried, dead material not capable of the vegetative propagation that would be needed in order to test chemicals. Neither did he have a supply of seed for these various species.)

(d) Has sufficient time elapsed after spraying for the responses to occur? The length of time may vary from two to six or eight weeks for woody vegetation, depending on its state of growth, inherent susceptibility, etc. A given plant may, in fact, be dead (incapable of regrowth) for some time before it is really obvious and vice versa, that is, it may appear to be dead and resprout.

(e) And (in Vietnam) was it possible to make observations of the kind necessary to evaluate fully the chemical effects? South Vietnam is actually engaged in a shooting, bloody war; therefore, any movement within the country of personnel who are there to help them, though noncombatant, are governed by very stringent regulations. Included in these regulations is a rule that Intelligence has to grant permission in order to take a road trip anywhere outside of Saigon. If Intelligence indicates that such a trip would be inadvisable, this becomes the law. Even if Intelligence indicates that it is all right to go, an armed escort is required to accompany the traveler. In order to make these ground trips, advance planning is necessary to acquire Intelligence permission and for arrangements to be made for a suitable armed escort. This is not a personal choice and is beyond the control or the responsibility of the individual. Thus, opportunities for close inspection were relatively rare.

Remember, too, that the greatest effect achievable or to be expected under any circumstances as a result of chemical sprays may be roughly compared with the condition of a US hardwood deciduous forest in winter. A much better appreciation of this condition, insofar as it pertains to increased visibility, can be obtained by viewing such a forest with snow on the ground, whether it is seen from the ground or from the air. Such an effect, if achieved, may be transitory, not because the "killed" vegetation comes back to life but because of seeds giving rise to new plants and because understory species that received sublethal quantities of spray are capable of growth to fill in areas formerly dominated by the killed trees. The rapidity of this regrowth will be dependent on the prevailing growth conditions and would be expected to be more rapid during a rainy season.

The rating of effectiveness of the 2,4-D and 2,4,5-T chemical tests is therefore based on the above factors and is primarily concerned with the killing effect of the chemicals. As the kill developed to a maximum, observations were made in the best manner available or possible. It was not always possible to obtain colored photographs because of light conditions, rainstorms, other missions of higher priority cancelling planned air trips, or lack of communication and/or understanding achieved with VN pilots as to positions of the aircraft desired in relation to the sun in order to get the best pictures. Efforts were made to take enough pictures so that slides could be furnished to the MAGRD-CDTC, to ARPA, and to Crops Division, Biological Laboratories.

The killing effect of the 2,4-D and 2,4,5-T chemicals should not be confused with "degree of defoliation" or "increase in visibility" as such. It does follow, however, that a reasonable or high percentage of kill of the vegetation (including roots) will ultimately lead to a reasonable or high degree of improvement in visibility despite the fact that in transition certain species may die but not drop their leaves. Nevertheless, other natural causes can bring about the falling of dried, dead leaves such as high winds or heavy rains. In this connection a VN agricultural official estimated that under natural conditions as many as 90 per cent of the jungle species do not ordinarily drop their leaves in concert in any given season. These leaves are dropped only as their physiological condition naturally deteriorates.

The action of cacodylic acid (CA) in tests detailed below requires an approach of understanding that differs from that for the action of the 2,4-D and 2,4,5-T chemicals. CA appears to be a desiccant in its action; that is, on contact with the foliage in sufficient quantity, drying and shrivelling of the leaves occurs relatively soon compared with the time required for this to occur as a result of exposure to the previous chemicals. Environment and growth factors affecting the vegetation appear to have a relatively small effect on the action of CA on the foliage. However, no tests with this material were exposed to heavy rain following application (the material, called ANSAR, is fairly soluble in water). So the tests with CA were rated on the over-all ability to cause desiccation of the foliage only. It is entirely possible that even though all the foliage of a substantial portion of the vegetation was dried, the implication that the vegetation was killed is not warranted until conditions for active growth return. The rating of this chemical was, therefore, on its effectiveness in drying the green foliage.

B. VARIABLES

In the tests that follow it should be readily apparent that many variables are beyond control. Once the spray has left the nozzles no control exists. Even the most exact planning as to:

Swath width and length,

Ground deposition rate desired,

Amount of chemical required,

Flow rate,

Particle size range,

Altitude,

Airspeed,

Time of day for inversion conditions and weather, and

Spraying the area desired (aimability)

can essentially be nullified unless at least reasonable adherence to standards for these factors is in fact obtained. Many of these factors are inextricably related and one can never be entirely sure of what has been achieved in the way of performance of equipment of equipment (especially if it has not been calibrated) or in spray deposition except by judging the over-all biological result. It is too frequently impossible in judging this result to pin down a single cause for failure to achieve an optimal effect. On the other hand, if the effect is good, it follows that all of these factors as well as a host of biological factors have been reasonably well met.

To exemplify the above, progress reports, memos, and other documents are presented (Sections IX through XI of the Supplement) that indicate the impressions of the writer at the time, or shortly after, the tests were performed but before the spray effect had developed. It can be easily noted, for instance, that for Test 1 on 10 August, the writer's sketch (Section X of the Supplement) of the sprayed area reflects what was planned and was requested of the pilots. The writer was told by the pilots that the sketch was reasonably accurate. The VN Province Chief, however, later presented his sketch of the sprayed area (just after the mission), which was proved to be much more accurate by aerial observation on 28 August and was so reported after that time (Section XI of the Supplement). It should be noted that five passengers were aboard the H-34, three of whom were VN. The sense of curiosity is generally highly developed in these people and the doorway of the H-34 is not large. Additionally, the 200-gallon HIDAL tank is carried internally opposite the door. Suffice it to say, the writer's observations were made from the fourth best available place of observation and Mr. Johnson had none.

In regard to Test 2, the reports written after spraying but before spray effect was evident (Sections XI, XII, and XIII of the Supplement) include an unintentional deviation from the plan but reflects an effort to present the

facts with a conversion to linear distance based on the 2 minutes 45 seconds of spraying time at an air speed of 120 miles per hour. The spraying time information was supplied by Sgt. Roe and later Captain Cadori confirmed that the first pass was made at an altitude closer to 125 feet than the 75 feet requested. Because the observer was on the ground at the time, he was unable to talk with these men until some time (a day or so) after the spray was delivered.

The point is made that in executing these experiments, where the writer was responsible and desirous of trying to control the variables as much as possible, the flights were performed by others. Although their full cooperation and effort was appreciated, variations could not be prevented from affecting the operation.

Later, when the USAF "operational testing" was performed (Appendix, Part B), technical guidance leading to these "tests" could scarcely enter the echelons, much less influence them. The USAF spray pilots were the major point of contact and were as cooperative as they could be under the circumstances but they, of course, had to be and were responsive to USAF orders. Some of these men had seen, and appreciated what they saw, of the vegetation control at Camp Drum, New York. This work is reviewed in a five-minute movie with sound. A copy was left in Vietnam and a copy was forwarded to ARPA in early March. In this connection, Section II of the Supplement indicates the state of the art as of 24 February 1960, and was prepared for information in response to a query originating in the US Third Army area pertinent to a Fort Stewart, Georgia, vegetation problem.

The tests detailed in the Appendix had as their ultimate purpose the improvement of visibility from the air and on the ground in the kinds of vegetation encountered in Vietnam along roadsides, in jungles, and in mangrove areas. The chemicals used in most tests, and recommended for large-scale use, are vegetation killers of the growth-regulating type. The implication is inherent that killed vegetation would allow improved visibility in one to two months and be relatively long lasting, depending on the degree of kill achieved. It had been indicated to the writer before he left the US in July that time for effect of the sprays to develop was not critical.

For general locations of test sites the reader is referred to the marked map of Free Vietnam in Section XIV of the Supplement. Section VII presents the chronology of tests in tabular form.

V. DISCUSSION

It should be noted that other tests were performed in addition to the 18 already listed; however, it was not always possible to revisit and observe results and the record for these is therefore incomplete. In some instances informal information was received concerning these and in each case the response was favorable. Word appeared to get around and this gave rise to requests from many areas for "testing." Obviously, these could not be allowed to interfere with the scheduling of the major efforts, although some were accommodated if they were feasible and could contribute to the research effort. Several were referred to the US-VN planning committee for consideration as to whether they should be included in target selections.

The major record of results consists of colored slides, several of which were distributed some months ago. It is planned as soon as possible to make available duplicate sets covering the entire period. A reasonably complete set has been arranged and left with MACRD-CDTC.

In connection with the one aerial spray of cacodylic acid (Test 13), the writer could not in conscience recommend unlimited use of this material for spraying jungles or roadsides at ten pounds per acre because more research information is needed on duration of effects, safety of handling, compatibility with systems (the material is corrosive to brass; the HIDAL has a fiber glass tank and stainless steel booms, but some brass connections and brass nozzles) and, most important, toxicity to humans and animals either by contact, inhalation, or ingestion. To the writer's knowledge this test was the first aerial release of this chemical anywhere at rates of this magnitude. Toxicity test information by others indicates that this material is less toxic than DDT. Its action on foliage at this rate appears to be that of a desiccant, with little evidence of selectivity among the unknown jungle species that were sprayed. About one month after spraying there was some evidence of new leaves appearing on certain species where the old foliage which had been sprayed was totally brown and shrivelled, or had fallen.

Although the sprays delivered under USAF control were not the official responsibility of the writer, it is unfortunate that certain technical aspects pertinent to the spraying could not be communicated or, if communicated, appropriate appreciation appeared lacking.

For instance, the chemicals had been represented by the writer as "vegetation control agents" or "vegetation killers" and not "defoliants," yet on 17 January (after sprays by the C-123 equipment on 14 and 15 January) a VN letter of protest was received from a rubber plantation claiming that 60,000 rubber trees had been killed. This seemed to surprise all concerned. The writer was approached after the fact, yet he had not known which particular targets had been selected for spraying. Otherwise, he could have advised against spraying jungle in proximity to a rubber plantation. (In this

connection, it definitely appears from the evidence available that the plantation was not directly sprayed, but the concentration of vapors from the chemicals was sufficiently high to affect the rubber trees when the prevailing wind reversed direction some four or five hours after spraying). Many times extreme care was urged by the writer both on target selection and on spraying to avoid areas known to have such crops as citrus, rubber, tobacco, bananas, sweet potatoes, manioc, papyas, grapes, melons, rice, and the like. Perhaps this instance served an expensive but useful purpose in making the point. Many of these crops are far more sensitive to the spray or its vapor than the various unknown jungle species appear to be.

Another instance is that the C-123 equipment had not been calibrated for spraying the relatively viscous materials for which it was being used for the first time. This need was pointed out several times to several people; nevertheless, the system was still not calibrated when a second set of targets was sprayed in mid-February.

The onset of the dry season reached proportions toward the end of January that prompted a memorandum to the Chief, R&D Division, on 29 January (Section XV of the Supplement). This memorandum was brought to the attention of MAAG C3 the following morning.

The dry season markedly curtailed growth of upland species by the end of January. However, there were areas sprayed by the C-123's in the middle of January where very good effects were observed, namely, in two mangrove areas where lack of water did not limit growth. By mid-February large areas of mangrove were leafless.

During this assignment the writer was subjected to many preconceived notions and misconceptions from others on the general subject of "defoliation." Some felt that if "defoliation" did not remove the trees or cause them to fall, the research was useless — either total visibility or none. Others were intermediate in attitude, granting that vertical visibility would be improved but unable to visualize improved horizontal visibility. The ones who said "any increase in visibility would be worthwhile" were those who were faced with fighting in dense vegetation or being ambushed from it, or pilots or aerial photographers who needed to see down through it. (It should be noted that successful enemy ambushes have been conducted without firearms in hand-to-hand combat.)

Progressing from "defoliation" (an all-purpose defoliant has yet to be discovered) to "vegetation control" (killing the vegetation) seemed beyond comprehension for some, and when it was stated that two to six or eight weeks might be required for a major improvement in visibility, the reaction was most negative. That the French spent huge sums of money unsuccessfully fighting for several years an enemy they couldn't see in the jungle made no apparent difference. The current conflict does not seem to be nearing a successful conclusion, on the contrary, the intensity of the conflict appears to be increasing. Under these conditions it appears that the combat success

of friendly forces should be expedited if possible by improved visibility in fighting areas, or by exposing enemy roadside ambushes, jungle trails or bases if that improved visibility can be feasibly provided. Unfortunately, the rainfall maps (Section XVI of the Supplement) were not available to the writer before the ground observation trip on Route 15 on 26 January (Section XV). Searches for other technical literature had been so disappointing that it did not seem possible that rainfall maps would be available. Nevertheless, the data they contain for the dry months of December through February certainly indicate that growth-regulator chemicals would have their immediate action impaired to a marked degree. Soil moisture continually diminishes, with only one inch or less of rain per month on the average for large areas. December had some residual moisture carry-over from November and October, but January and February show exceedingly dim prospects for active growth. Thus, the USAF spraying was started in upland areas during the worst time of the whole year (mid-January) from the standpoint of immediate chemical effectiveness. Because a high percentage of the jungle species do not ordinarily drop their leaves at any given time in the year (according to the VN authority listed in Paragraph 4 of Section XV of the Supplement), a distinct possibility exists that the action of the chemicals already sprayed will become obvious where conditions again favor growth. Mangrove areas along Route 15, where lack of water is not limiting, were successfully sprayed in the same period (mid-January) and excellent results were apparent in two weeks, with a very high percentage of the sprayed mangrove denuded in one month.

VI. CONCLUSIONS

In relation to the work reported here it is concluded that:

1. In general, with regard to the total program,

a. The chemicals recommended for use, namely the esters of 2,4-D and 2,4,5-T, are sufficiently active to kill a majority of species* encountered in Vietnam if:

(1) They are applied properly to the vegetation

(2) They are applied during a period of active growth of the vegetation.

b. Color photography is the best means of recording the effects of sprayed chemicals, but even the best picture can fall short of being fully descriptive.

2. In regard to the research work conducted during both work periods, it can be concluded that:

a. Chemicals of the type being used are fully effective only when the vegetation is in a period of active growth (See Sections I, XV, and XVI of the Supplement). Lack of rainfall in the period between December and February induces a state of dormancy, and spraying should be curtailed during this period. Spraying of mangrove or other species growing where water is plentiful could continue.

b. Chemicals of promise have been tested successfully on a small scale, but more information concerning their use must be obtained through additional research (See Tests 14 and 16 in the Appendix). Extra-continental and in-house research in this area should continue. Especial attention should be paid to cacodylic acid as one of the immediately available and promising candidates. Further testing with Diquat is indicated; however, this product is currently available only in restricted quantities.

c. Technical information must be included in effective decision-making. Its lack may result in inefficient use of chemicals or may have serious economic or public health consequences (See Appendix, Part B).

d. Incorporation in the HIDAL and the C-47 spray system of a flow meter showing rate of flow (gallons per minute) as well as the gallonage sprayed would be a useful device in spraying liquids of various viscosities. Calibration of these systems with the chemicals to be used is desirable.

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* See Sections II, XIII, and XV of the Supplement.

e. The HIDAL equipment can serve a useful purpose, but could be improved if it had a higher flow rate, especially if such higher flow rate could be adjusted for several rates for dispensing solutions of various viscosities (See Appendix, Tests 1, 13, and 14).

f. The C-47 system could be made useful if it were re-engineered to provide greater versatility in spraying adequate quantities of the required solutions (See Supplement, Section IV).

g. The 14B spray tank would be of greater use if it were simpler and more easily assembled, checked out, and operated (See Appendix, Test 2).

h. Continuous spray booms for fixed-wing aircraft (across and under the fuselage) would allow greater freedom of choice of altitude for spray releases (See Appendix, Tests 7 and 8).

3. In relation to the operational portion of the second work phase as conducted by the USAF (See Appendix, Part B), it can be concluded that:

a. The recommended chemicals will work effectively, as demonstrated by the two operational tests on mangrove that were actively growing in swamp areas.

b. The chemical effect is seriously limited by dormancy in vegetation, as evidenced by four operational tests on upland vegetation that was dormant because of drought (See Supplement, Section XV).

c. The C-123/Hourglass system should be calibrated for spraying the recommended materials. Additionally, the inclusion of a flow rate meter in the system would enhance its experimental and operational use for solutions of different viscosities (See Supplement, Section XV).

d. Operational tests with uncalibrated equipment can provide only minimum information because application rates remain uncertain. Thus, logistic and operational factors for future operations cannot be predicted (See Supplement, Section XV, and Section IV, B of this text).

e. Operational tests must be guided by adequate technical advice until operational elements achieve a higher degree of familiarity with the materials and the effects of climate, vegetation types, and associated factors (See Supplement, Section XVII).

VII. RECOMMENDATIONS

On the basis of the work done in South Vietnam and the resulting conclusions, it is believed that the following recommendations merit careful consideration and implementation.

1. That the use of appropriate formulations of 2,4-D and 2,4,5-T be exploited for immediate use pending development of more active and rapid-acting chemicals. Simultaneously, explore the possibility of enhancing the effectiveness of these formulations by suitable additives.

2. That research work be conducted toward finding more rapid acting and effective chemicals for defoliation and plant killing.

3. That these chemicals be screened in areas such as Vietnam, Thailand, or other countries with similar vegetational types, as well as in temperate areas, because of the wide variation in vegetation response depending upon species, climate, and other associated factors. The required research could be performed with less interference in a country at peace.

4. That both the extra-continental research and the screening programs, as well as any future operational tests, be guided in all stages by competent technical advice. It is necessary that these technical advisors be on the scene and that they have a major voice in decisions. This is especially important when the safety of economic crops, possible toxicity, and validity of scientific data are concerned.

5. A technically qualified civilian staff be developed for this increase in effort. It is currently estimated that a minimum of 12 civilians is required, supported where necessary by an adequate number of military personnel, in order to handle all phases of the work including in-house screening, contract monitoring, and test-site operations.

6. At each test site the research should be conducted under the direct supervision of a civilian scientist supported by a staff composed of at least three technically trained civilians and a sufficient number of military personnel to support the effort. The lack of an adequate-sized technical staff hampered the accomplishment of the research objectives in Vietnam during the research phase and prior to USAF spray operations.

7. Thoroughly evaluated cacodylic acid and Diquat, two promising candidate agents, as soon as possible in order to exploit their potential.

8. That the HIDAL be re-engineered to provide increased flow rates as required to achieve adequate deposition of the necessary chemicals and that provision be incorporated to adjust flow rates as necessary.

9. Accurately and completely calibrate all spray devices prior to use for flow rate, droplet size, etc, using the actual chemical solutions or simulants with identical physical properties.

10. Provide a professional photographer to record results of tests with color photos.

11. Assign a helicopter and a light aircraft (L-20 or similar type), complete with operational and maintenance crews, to the civilian scientist in charge for use in spray missions and for aerial observations of results.

12. Continue to improve disseminating devices for both aerial and ground use.

13. Include the civilian scientist in charge in all decision-making discussions pertaining to use of vegetational sprays.

APPENDIX

A. DETAILS OF TESTS

1. Test 1

a. Description

Date of Spray: 10 August 1961, about 1650 hours.

Place: Roadside areas north of Kontum. The vegetation consisted of relatively dense upland forest species with trees from 10 to 60 feet tall; species unknown.

Chemical Sprayed: It was planned to spray Dinoxol for deposit rates of one and two gallons per acre (four and eight pounds per acre). This was to be accomplished by overlapping a portion of two separate swaths. Despite the plan, the following was achieved. A total of 50 gallons of Dinoxol was sprayed for an estimated swath width of 200 feet, laying separate single-pass swaths on each side of the road with no overlap. Deposited evenly over a 200-foot swath, at one gallon per acre, 50 gallons of chemical could be sprayed for a distance of about two miles. Measurements of the area actually sprayed were impossible to obtain.

Equipment: H-34 helicopter equipped with HIDAL (Helicopter Insecticide Dispersal Apparatus, Liquid).

Flow Rate: According to the literature, light oil sprays are used, the system is relatively fixed for delivering one-half gallon of spray per acre if flown at about 50 knots at an altitude of about 75 feet. Other rates are possible by varying airspeed and altitude or spraying the same swath twice, but little data were available for adjustment. The pump pressure was 40 pounds. With less viscous liquids a flow rate of about 25 gallons per minute has been obtained.

Airspeed: Requested 50, obtained 45 knots.

Altitude: Requested 75 feet, varied between 50 and 100.

Wind: Crosswind very light from the west, estimated at less than 5 knots.

Weather: Overcast and cloudy. A rainshower was observed a mile or two east of the area which, the writer was informed, later passed over the sprayed area.

Observation Dates: Aerial flyover, 28 August; ground trip, 11 October.

b. Results

Very good to excellent effects were observed on 28 August, the area being visible from the air on approach from a distance of about 5 miles. No evidence was observed of overlapping swaths, nor were the swaths of equal length or adjacent to one another along the road. The vegetation showed clearly that leaves were turning brown.

It is estimated that 70 per cent of the trees were either dead or dying on 11 October.

c. Discussion

It was not possible to observe the results of these sprays with greater frequency because of several interfering factors. The site was quite distant and communications were intermittent at best, thus arrangements for ground security were difficult for the VN to make, especially when VC (enemy) activity was fairly frequent and often extensive in this region.* The airstrip at Kontum was often closed for relatively long periods because of the rainy season.

After the spray mission the HIDAL was grounded because of damage to the H-34 fuselage. It was not until 12 January 1962 that it was used again. Its performance on three tests (1, 13, 14) was excellent as judged by the results achieved.

Figures 1 through 4 show the results of Test 1 two months after the roadside north of Kontum was sprayed with Dinoxol with the HIDAL and H-34 helicopter.

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* Reference: "Weekly Intelligence Digest," No. 41-61 of the Pacific Command, 20 Oct 1961, pages 8-10.

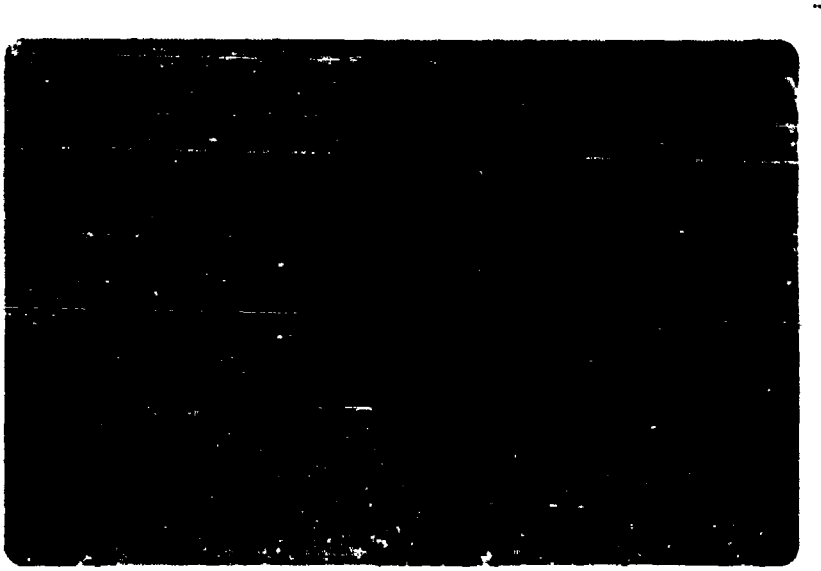

Figure 1. Effects of Test 1 Two Months After Spraying.

Figure 2. Effects of Test 1 Two Months After Spraying.

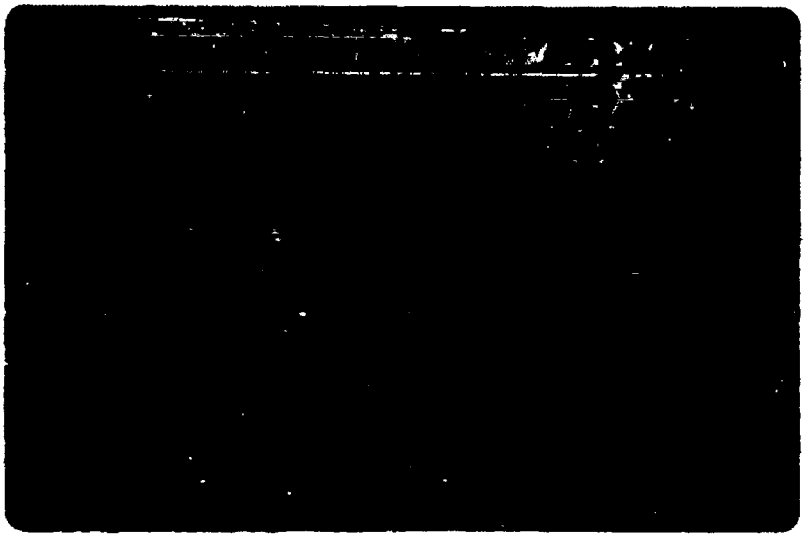

Figure 3. Effects of Test 1 Two Months After Spraying.

Figure 4. Effects of Test 1 Two Months After Spraying.

2. Test 2

a. Flight Description

Date of Spray: 24 August 1961, at about 1030 hours.

Place: Roadside 76 to 80 kilometers north of Saigon near Chon Thanh. This test site was selected by President Diem. The vegetation consisted of upland, relatively dense to open forest of unknown species. Tree height varied from about 10 to 35 feet.

Chemical Sprayed: It was planned to spray about 10 linear kilometers of roadside in three different passes in such a way as to spray about four kilometers on each side, with a portion of one side being sprayed twice to give rates of one and two gallons per acre. This was accomplished by spraying 200 gallons of Dinoxol. A 300-foot swath was planned, and for the length involved would have been close to 225 acres. The portion of the first swath that received the double spray was only about 0.8 kilometer instead of two kilometers as planned.

Equipment: The C-47 spray rig was used for this test.

Flow Rate: The pump pressure was set at 30 pounds (the maximum) and calculations later indicated 73 gallons per minute were discharged. The spraying time later was stated to be 2 minutes 45 seconds.

Airspeed: 120 miles per hour.

Altitude: Requested 75 feet above trees - first pass east side at about 125 feet. Second partial pass east side at about 75 feet. Third pass on west side about 75 feet.

Wind: Estimated at about five to eight knots and about 10 degrees off flight line from east to west.

Weather: Cloudy and overcast.

Observation Dates: The writer was on the ground during the spray operations. Subsequent observations were all made from the air on 28 August; 7, 8*, 20 September; 16, 17**, 20, 28, 31 October; 7, 16 November, 2, 15 December; 8 January.

b. Results

Although it was readily apparent that the spray had been effective on perhaps 30 to 50 per cent of the tree species growing on this site, it appeared that either a sublethal amount of spray had been delivered, penetration was insufficient, or the unknown species present were more resistant to the chemical. The third spray pass that was made had obviously been

* Repeat spray west side same material, same rate, because first spray had drifted about 300 feet west of intended placement. See Test 4.

** See Test 8.

delivered too far down wind and had been deposited too far from the road. There was little evidence of increased effect from the area that received the intended double rate. The effect of the initial spray was rated questionable.

c. Discussion

The results obtained in this test left much to be desired. It was not readily apparent why the response compared so unfavorably with the results of Test 1. Several things were suspect, including (a) insufficient amounts of the chemical deposited, (b) insufficent penetration, or (c) the greater resistance of the species at this site to the mixture of chemicals used. Although (a) and (b) above could have been attributed to the C-47 system, it was not directly suspect at this time (7 September) because there was little evidence of increased effect in that portion that received the double application. It was believed that despite the excessive altitude of the first pass, surely the area that had received a double spray could have shown some obvious increased response. (See Section IV of the Supplement for a discussion of problems encountered in using the C-47 system.)

Special cards placed on the downwind of the eastern side in a cleared spot adjacent to the road indicated what was considered a respectable coverage. Some of these cards were intentionally placed under the cover of existing vegetation, but none were placed in the forest because the Vietnamese were reluctant to let anyone out of sight. It is believed that perhaps the bulk of the first two sprays actually were delivered in the cleared area adjacent to the road.

It was decided on 7 September to respray the west side of the road in an effort to put the swath where it was desired.

3. Test 3

a. Flight Description

Date of Spray: 25 August 1961, about 1035 hours.

Place: Mangrove area southeast of Saigon on a line generally toward Cap St. Jacques and a little more than halfway there. Mangrove was the predominant genus, varying from 75 to 90 per cent of the vegetation, but unknown species were present.

Chemical Sprayed: Dinoxol was sprayed at this site. The agent of choice indicated by earlier research elsewhere indicated 2,4-D formulations as being two to six times more effective than those of 2,4,5-T. Because no significant quantity of 2,4-D was on hand other than in the Dinoxol, it was planned to spray two gallons of this material per acre in order to get four pounds per acre of 2,4-D on the vegetation. A total of 85 gallons was sprayed on a strip about 1.1 miles long.

Equipment: A 14B spray tank was functioned from an AD6 aircraft.

Flow Rate: The tank was set to deliver 85 gallons of water in 20 seconds and tested for this delivery. The spray was delivered in 20 seconds.

Airspeed: Requested 175 knots, actually 178 knots.

Altitude: Requested 75 feet; delivery was made initially at 75 feet but climbed to about 100 feet during the delivery.

Wind: Crosswind estimated at less than 10 knots.

Weather: Bright and clear.

Observation Dates: All observations have necessarily been made from the air. This area is almost inaccessible otherwise, except by boat. It was observed on the following dates: 7, 13*, 14*, and 20 September; 15, 24, 28, and 31 October; 7 and 16 November; 2 December; 3 January.

b. Results

This test is rated very good to excellent. Five months later the regrowth in the swath was still subdued. The pattern of the swath shows a relatively sharp line on the upwind edge that feathers off downwind where sublethal deposit was obtained. The mangrove species are undoubtedly susceptible to the chemicals used. The trees were killed and many were leafless in a month's time.

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* See Tests 5 and 6.

c. Discussion

The spraying of mangrove was not originally included in the program, but was included after the arrival of the writer. Chemicals had been requested on the basis of the original program; thus, there was not a supply of 2,4-D formulation available at the time of this test. A volatile ester was requested and the ethyl ester was received on 4 September, but it was in a water-dilutable form. An oil-based formulation would have been preferred because of the heavy rains encountered in Vietnam, which can degrade the effect of chemical preparations that are ordinarily diluted with water.

Dinoxol performed very well against the species encountered in this test.

The 14B tank was unloaded and instructions given to pack it for return to the lender according to the previous plan.

Figures 5 and 6 show the results of Test 3, in which Dinoxol was sprayed on a mangrove area with a 14B spray tank and AD6 aircraft.

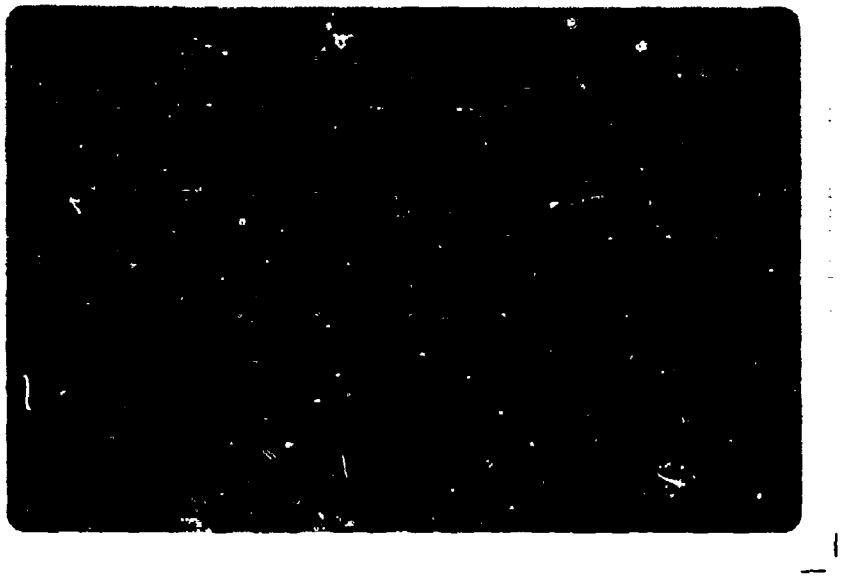

Figure 5. Effect of Test 3 on 7 September 1961, Two Weeks after Spraying.

Figure 6. Effect of Test 3 on 1 February 1962, Five Months after Spraying.

4. Test 4

a. Flight Description

Date of Spray: 8 September 1961, about 0930 hours.

Place: West side spray of roadside in Test 2 had drifted west away from road on 24 August release. This test was performed to spray the area originally intended.

Chemical Sprayed: Dinoxol - 100 gallons. A single pass was made releasing the chemical over a distance of about four kilometers.

Equipment: C-47 spray rig.

Flow Rate: Maximum at 30 pounds' pump pressure. Estimated about 73 gallons per minute.

Airspeed: 120 miles per hour.

Altitude: Estimated at 75 feet above trees.

Wind: Almost head wind estimated at less than five knots; however, after the spray was released and the plane turned around to fly at tree-top level over the center of the road, droplets of spray impinged on the windshield of the aircraft.

Weather: Bright and clear.

Observation Dates: 20 September and 16 October.

b. Results

The development of the spray effect was much like that previously described for Test 2 and was rated questionable. By 16 October it was estimated that only 30 to 50 per cent of the trees were dead or dying.

c. Discussion

After the observation of 20 September and the observations of two more releases with this equipment (Tests 5 and 6), its performance was seriously questioned. It did appear that sublethal rates were being deposited and that penetration of the spray in the forest canopy was not sufficient. This test had shown that the over-all effect was certainly out of line with results achieved in Tests 1 and 3.

5. Test 5

a. Flight Description

Date of Spray: 13 September 1961, about 1015 hours.

Place: Mangrove area near site of Test 3.

Chemical Sprayed: Concentrate 48, a water-dilutable form of the ethyl ester of 2,4-D, containing three pounds of active ingredient per gallon. About 100 gallons (two drums) of chemical were sprayed to obtain rates of one and two gallon per acre. One swath was put parallel to that of Test 3 and received a partial repeat spraying to obtain a double rate. Two other swaths were delivered at right angles to the first.

Equipment: C-47 spray rig.

Flow Rate: Maximum, with 30 pounds' pump pressure. Estimated 73 gallons per minute.

Airspeed: 120 miles per hour.

Altitude: About 75 feet.

Wind: Estimated five to seven knots, crosswind for first pass. In-wind for last two passes.

Weather: Scattered clouds with intermittent sunshine.

Observation Dates: 14, 20 September; 15, 24, 28, 31 October; 7, 16 November; 2 December; and 3 January.

b. Results

Results were much inferior to those of Test 3. As the effect developed, isolated trees, assumed to be of the same species, showed striking fall coloration; however, these trees constituted a very small percentage of the vegetation in the area. Ultimately, the effects of these sprays became almost unidentifiable within the whole period of observation. There was little or no evidence of increased effect of the two-gallon-per-acre rate of spray.

c. Discussion

A rainstorm is known to have fallen on the area the day after spraying. Because this formulation is dilutable with water, it is possible that its effectiveness could have been reduced. During the spray operation it was noted, too, that some of the spray exhibited a tendency to rise, thus reducing deposition of the chemical in the intended area.

6. Test 6

a. Flight Description

Date of Spray: 14 September 1961, about 1045 hours.

Place: Mangrove area near sites of Tests 3 and 5 but across a river from them.

Chemical Sprayed: Trinoxol, an oil-dilutable form of an ester of 2,4,5-T, containing four pounds of active ingredient per gallon. About 50 gallons (one drum) of this chemical was sprayed to obtain rates of one and two gallons per acre by a partial repeat spray of a single swath.

Equipment: C-47 spray rig.

Flow Rate: Maximum, with 30 pounds' pump pressure. Estimated 73 gallons per minute.

Airspeed: 120 miles per hour.

Altitude: Estimated 75 feet.

Wind: In-wind flights, heading 240 degrees. The wind was estimated at 18 knots with gusts from the west.

Weather: Cloudy and overcast. A rainstorm fell on the area within 10 to 15 minutes after spraying.

Observation Dates: 20 September; 15, 24, 28, 31 October; 7, 16 November; 2 December; 3 January.

b. Results

Relatively long-lasting effects were achieved; however, it appeared that a smaller percentage of the trees were affected than in Test 3. Little evidence was noted of increased effect in the portion of the swath sprayed twice. This test is rated fair.

c. Discussion

This test achieved the distinction of being the best so far using the C-47 spray rig. It should be borne in mind that at the time of its performance the results of Test 2, the first test with this equipment, were in the relatively early stages of development.

Considering the meteorological conditions prevailing at the time of spray and shortly thereafter the results were surprisingly good. It is believed that, although true comparisons are not available, this demonstration indicated the desirability of using oil-dilutable chemical preparations for large-scale tests confirming the results of work in the US. Rains of the intensity of those in N are not usual in the US.

7. Test 7

a. Flight Description

Date of Spray: 17 October 1961, about 0845 hours.

Place: Test swaths were sprayed on forest vegetation near the airstrip at Bien Hoa.

Chemical Sprayed: Trinoxol was sprayed to obtain two rates of application. Three swaths were sprayed; the first swath was sprayed twice. Because of the short supply of Dinoxol on hand the fact that other tests were planned with it, Trinoxol was used instead. Three hundred gallons (six drums) of this material were loaded for this test and Test 8 jointly on the same flight. The attempted rates of deposition can only be stated as being somewhat greater than in any previous C-47 spray tests. Two major differences should be noted between this and the previous C-47 tests; (a) the time of day, which contributed to inversion conditions, and (b) the altitude of release, which was considerably less than that used previously in an effort to get the chemical down.

Equipment: C-47 spray rig.

Flow Rate: Maximum, with 30 pounds' pump pressure. Estimated 73 gallons per minute.

Airspeed: 120 miles per hour.

Altitude: Tree-top level.

Wind: Calm, still conditions prevailed.

Weather: Clear.

Observation Dates: 20, 24, 28, 31 October; 7, 16 November; 2, 15 December; 3, 8, 22 January by over-flights.

b. Results

Very good to excellent vegetation response was obtained in this test. Little distinction could be noted between the rates of spray. This difference may be expressed only at a later date as to the time required for, and the extent of, regrowth in that the swath receiving the heavier rate of spray will remain clear longer.

It is readily apparent that the altitude of release was very low, as demonstrated by the dual "tracks" of each single swath. Even the swath receiving two sprays does credit to the VN pilot in superimposing the sprays. The green strip in the middle of each swath is an unsprayed area.

c. Discussion

At the time of release, meteorological conditions were excellent for the test, which had as a major purpose getting the spray on the vegetation in sufficient quantity to be lethal.

The separate swaths were set out in this test to provide areas for others to test the possibility of burning in these areas and, if possible, to determine how soon after spraying the vegetation could be burned. It was decided by others after the sprays had been made that it would be an unsafe area for burning tests (See Section XVIII of the Supplement).

Had this cancellation been known in advance it would have been possible to spray from various altitudes up to and including 75 feet, an altitude from which a 200-foot swath could have been expected. We could then have obtained a tie-in on some earlier spray releases with this equipment where lack of inversion conditions had contributed to spray dissipation.

After release the spray remained visible for a relatively extended period and seemed to hover as a pair of horizontal cylinders while settling very slowly into the vegetation. There was very little air movement to disturb this phenomenon. It appears that the break-up of the material sprayed from the nozzles was exceedingly fine for the spray clouds to remain visible as long as it did. Yet the swath lines are relatively sharp, indicating almost vertical settling of the spray.

These observations practically dictated that the use of this equipment would have to be confined to periods of inversion.

Figures 7 and 8 show the performance and results of Test 7, in which a forest near Bien Hoa Airstrip was sprayed with Trinoxol with the C-47 rig. Figure 8 shows that vegetation is susceptible if it in fact receives the spray.

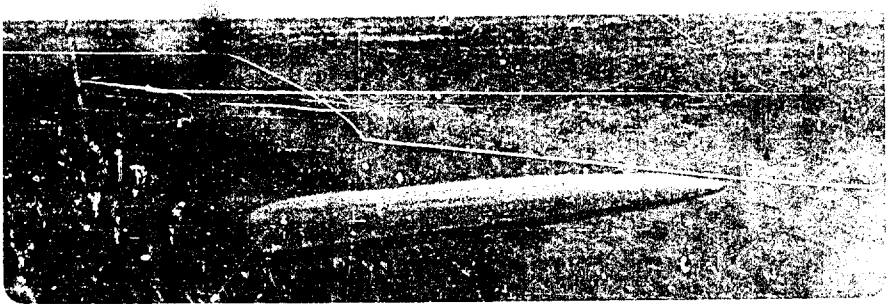

Figure 7. Test 7 Spraying. Note low altitude of Delivery and Separated Spray Clouds Prior to Settling.

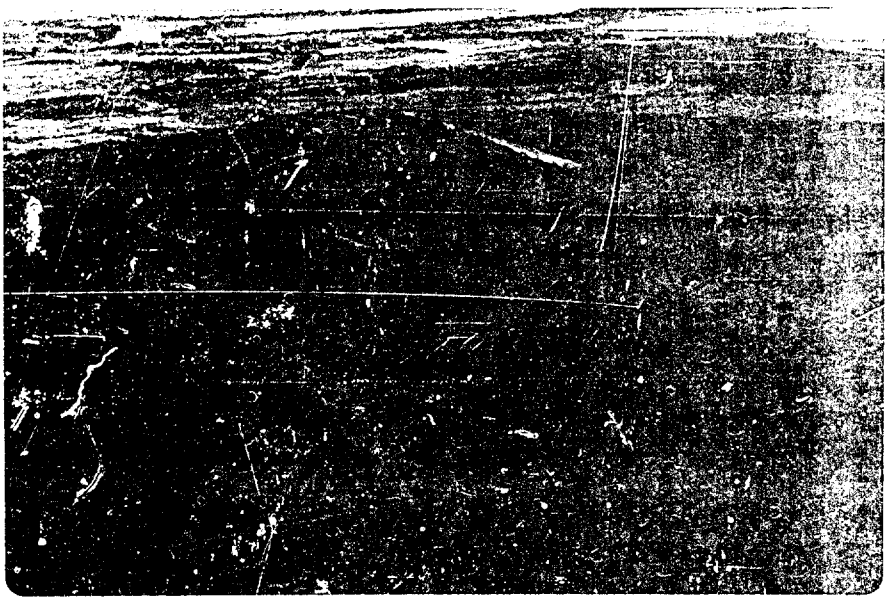

Figure 8. 3 January 1962. Effects 2½ Months after Spraying Three Swaths with C-47 Spray Rig.

8. Test 8

a. Flight Description

Date of Spray: 17 October 1961, about 0915 hours.

Place: Roadside area, same exact site as Test 2.

Chemical Sprayed: Trinoxol remaining from Test 7 was sprayed under excellent conditions at the start. Because there was little wind the pilot was able to fly up one side of the road and back down the other, thus spraying each side at a very low altitude. The exact amount of chemical sprayed here is unknown. Six drums of material had been loaded prior to spraying Test 7. The chemical was expended after two sprays on each side of the road.

Equipment: C-47 spray rig.

Flow Rate: Maximum, with 30 pounds' pump pressure. Estimated 73 gallons per minute.

Airspeed: 120 miles per hour.

Altitude: Tree top level.

Wind: Calm and still.

Weather: Clear.

Observation Dates: 20, 28, 31 October; 7, 16 November; 2, 15 December; 8 January by overflights.

b. Results

The effect of this spray is rated fair to good. Several trees had already been killed by previous sprays in these roadside areas. However, the current spray killed a relatively high percentage of those still alive.

c. Discussion

Before we left the area it appeared that inversion conditions were dissipating, as indicated by the tendency of some of the last of the spray to rise instead of settle. On the pilot's first run he misunderstood instructions and went off course, so that part of this run was over previously unsprayed forest; the east side thus had a portion that received only one spray. Nevertheless, it follows that if the killing effect is obtained the chemical was deposited in sufficient quantity, and unless killing is obtained many things can be suspect.

It is believed that, with aerial equipment uncalibrated for spraying the chemicals used, and in testing these chemicals on unknown species, so many unknowns were present it was practically hopeless to try to conduct a sophisticated test at this site. The basic effort here was to make sure that the species either were or were not susceptible to the chemical. Once this was established, refinement of rates and techniques could follow.

It is sincerely believed that the chemical was being deposited at sublethal rates in previous tests, with the equipment putting out as much material as it could, and with flights at a minimum safe speed and altitude.

Figure 9 shows the effect of Test 8. A roadside area 76 kilometers north of Saigon was sprayed with Trinoxol at tree-top level with a C-47 spray rig. The spray was superimposed on that of Test 2 (lower part of photo) and of Test 4 (upper) with Dinoxol.

Figure 9. Effect of Test 8 on 16 November 1961, One Month after Spraying.

9. Test 9

a. Description

Date of Test: 18 September 1961, about 1530 hours.

Place: Unwanted vegetation, trees, vines, shrubs, and grasses at ARVN Headquarters. Many of these species were unknown at the time and quite a few still are. However, those known to be present were banana, papaya, bamboo, grapes, melons, sugar cane, kapok, buffalo grass, and some leguminous trees whose leaves resembled those of mimosa and locust. Other plants had characteristics of Prunus species.

Chemical sprayed: Dinoxol. One drum (about 50 gallons) of chemical was added to the 5 to 10 gallons of fuel oil remaining in the tank from functional tests. This was a qualitative spray with the equipment towed on the ground. The air blast containing the spray was directed at the vegetation. It is estimated that about 25 gallons of solution were sprayed.

Equipment: A Buffalo Turbine, commonly used for orchard spraying in the US. The liquid to be sprayed is discharged under regulated pressure from nozzles located in the air stream supplied by a turbine. The model used is mounted on a single axle and in this test was towed by a jeep.

Flow Rate: Unknown.

Wind: About five knots on the ground, upper air current unknown but estimated at less than ten knots.

Weather: Cloudy. Heavy rain fell about one-half hour after spraying and lasted for about 16 hours.

Observation Dates: 19, 21, 25, 26, 27 September; 12, 23 October; 2 November; 19 December; 23 January - all on the ground.

b. Results

This test is rated excellent. A very high percentage of the vegetation sprayed responded to the chemicals. The upper air current carried some of the spray over a 10-foot wall and caused partial defoliation (and perhaps crown kill) of some sensitive tree species later thought to be kapok. Three kapok trees within the walled area also received this upper spray drift about one-tenth of a mile away and the windward side of the crowns of all three lost their leaves in about ten days. These portions of the trees failed to produce fruit in January, nor did they show signs of leafing out. Papaya was not directly sprayed and yet three of these trees were killed. Bamboo that was sprayed had dropped many leaves in ten days. A mature banana tree that was sprayed had fallen to the ground in ten days. Buffalo grass was tested for burning within one week and burned.

Sugar cane that was sprayed showed evidence of leaf necrosis but was not killed. Leguminous trees lost leaves as a result of the spray in ten days. Prunus-appearing species receiving the spray were killed.

c. Discussion

The effects of this test were developing concurrently with those of Tests 5 and 6, but were available for close and relatively frequent inspection. The responses developed relatively quickly and indicated that a rather wide array of vegetation types were capable of response. At this time, Tests 1 and 3 had given encouraging results, together with this test, in regard to the responses of several native species. Thus, three tests with Dinoxol using three separate disseminating devices indicated that the chemicals were effective. Tests 2 and 4 with Dinoxol were suspect and, later, Tests 5 and 6 using other formulations did not come up to expectations. All of these latter tests were performed with the C-47 spray rig, which was the only aerial system available for use. Tests 7 and 8 were conducted in such a way as to assure the deposition of chemical from this system. In addition, the chemical used was not the one of choice but had to be used as second choice because of its availability.

Test 9 has been listed out of chronological sequence primarily because all previous tests involved the use of aerial systems, the results of which were susceptible only to aerial observation, and the major effort, of course, was pertinent to those systems.

The conclusion of this test essentially marked the end of the first phase of the work.

Figures 10 through 15 show results of Test 9, in which Dinoxol was sprayed with a Buffalo Turbine towed by a jeep. The grass was sprayed, but trees were exposed to spray drift only in some cases.

Figure 10. Effect of Test 9 One Week after Grass, but not Trees, was Sprayed.

Figure 11. Ten Days after Test 9. Same Trees as Above.

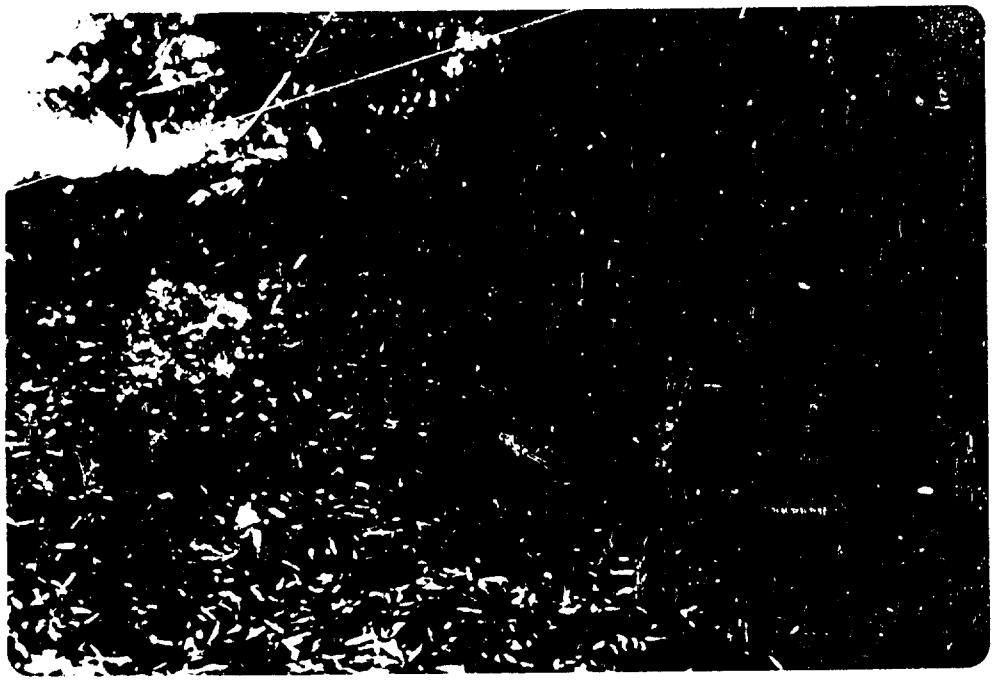

Figure 12. Effect of Test 9 One Week Later. Note leaf drop from bamboo.

Figure 13. Effect of Test 9 24 Days after Spraying.

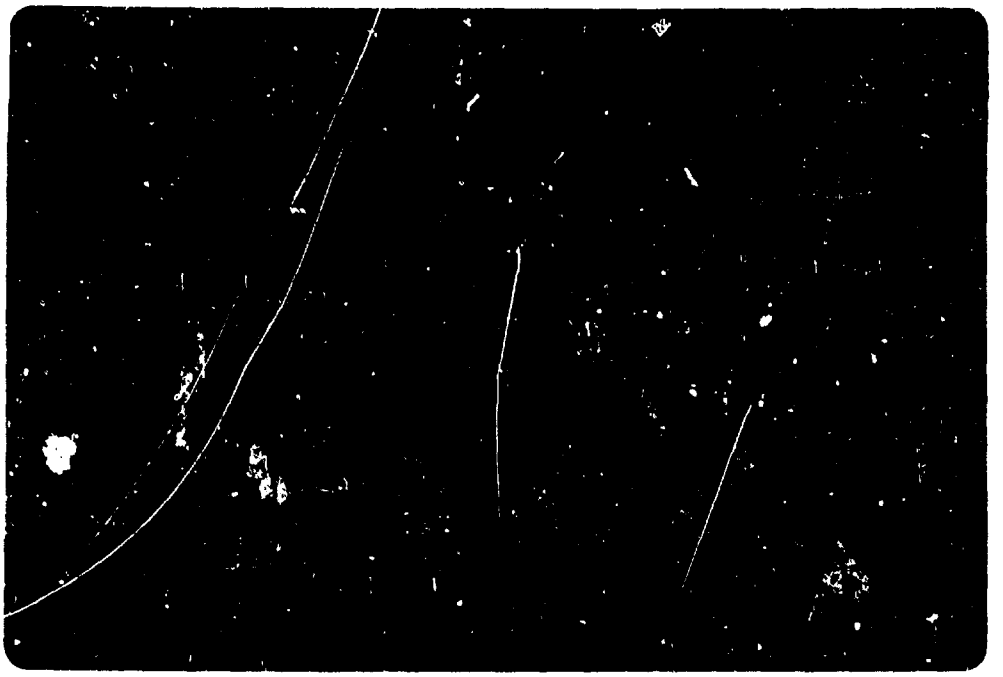

Figure 14. Effect of Test 9 after 24 Days. Tree was denuded in about 10 days; no sign of regrowth apparent.

Figure 15. Effect of Test 9 after 24 Days. Tree was denuded in about 10 days, no sign of regrowth apparent.

10. Test 10

a. Flight Description

Date of Spray: 29 December 1961, about 0900 hours.

Place: Site north of Route 15 between Bien Hoa and Long Thanh.

Chemical Sprayed: Code pink. About 50 gallons (one drum) of concentrate to be sprayed on a single swath of 25 seconds' flight time. Repeated sprays made over the same swath were calculated to be 500 feet wide and about 4400 feet long, roughly 50 acres. Three passes were calculated to be sufficient to expend the material; however, five and one-half passes were required.

Equipment: C-47 spray rig.

Flow Rate: Pump pressure at recommended setting of 20 pounds. Flow rate obtained was about 36 gallons per minute.

Airspeed: About 120 miles per hour.

Altitude: 150 feet.

Wind: Estimated less than five knots to less than 10 knots during passes. In-wind flights.

Weather: Partly cloudy; later, clear and bright.

Observation Dates: Visits on the ground are marked with an asterisk, otherwise observations were by flyovers: 3, 5*, 8, 10, 12, 16*, 19, 22, 24 January.

b. Results

The results were rated poor. It appeared that the deposition was sublethal. The swath was visible in the first week but failed to develop with time.

c. Discussion

This was a multipurpose test including the following objectives:

(a) To provide a swath for subsequent burning tests by others.

(b) To acquaint USAF personnel with difficulties of performance already experienced with this equipment.

(c) To test a concentrate of chemical.

USAF personnel* were given the assignment of depositing the chemical on 50 acres, with the choice of conditions, settings, and technique up to them. Discussions were held in which previous settings, altitudes, etc. were explained where other less viscous chemicals had been disseminated. It was pointed out that the present material was still more viscous. In all candor, these personnel knew more about this equipment than the writer ever hopes to know - it had been a personal part of their lives for some years. Nevertheless, they had not previously been faced with the problem of spraying these more viscous solutions. Furthermore, the equipment was calibrated for the light oil dilutions they used in spraying for other purposes. It was recognized at the outset that the equipment had been flown as low and as slowly as possible with a maximum flow rate, and that under these conditions the vegetation had responded (Tests 7 and 8). It was decided therefore to resort to multiple passes to achieve the deposition required, relieve the strain on the system by reducing the pump pressure to 20 pounds, and thus increase the droplet size and the chance of these larger droplets impacting where they were intended. By so doing the chances were also recognized that canopy penetration might be adversely affected if the particle size became too large.

In regard to the objectives:

(a) Permission to try burning was withdrawn by the VN as too dangerous (the area was used intermittently by VN charcoal burners).

(b) An appreciation of the problems (though unsolved by an unsuccessful test) was obtained by using personnel.

(c) Ground observation revealed evidence of high canopy effect that could have been expected to be considerably greater, but little evidence of lethal penetration of the canopy. It should be noted that the forest, although thick and green, was one month into the dry season and normal growth was probably already curtailed (See Test 11). This was the last time the writer had any connection with sprays delivered by this system, and was on the ground at the site when this test was performed preparatory to conducting Test 11.

The details of the parameters used for this test are not currently available, but have been reconstructed as accurately as possible from memory.

Figures 16 through 18 show results of Test 10, in which the pink code chemical was sprayed from a C-47 rig.

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* The cooperation and technical knowledge of these men were much appreciated by the writer. A reader receiving any other impression does so contrary to the intent of the writer.

Figure 16. Effect of Test 10 One Week after Spraying.

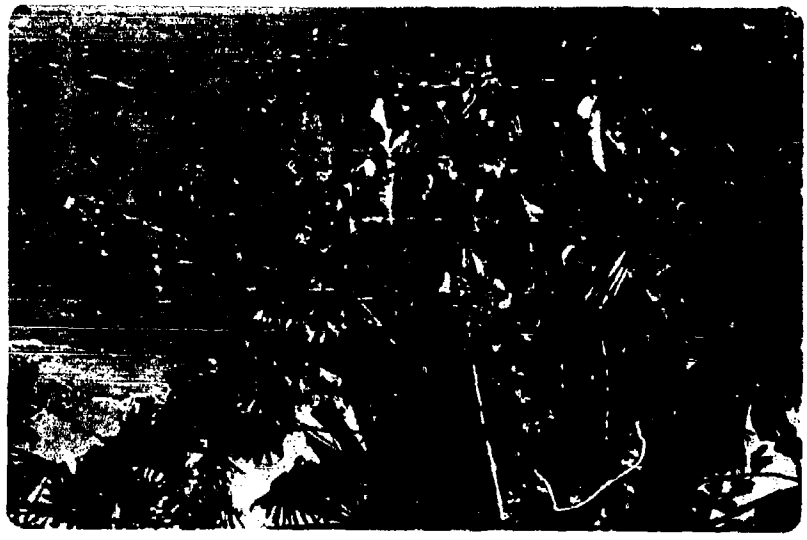

Figure 17. Growth Responses in Central Tree One Week after Test 10 Spraying.

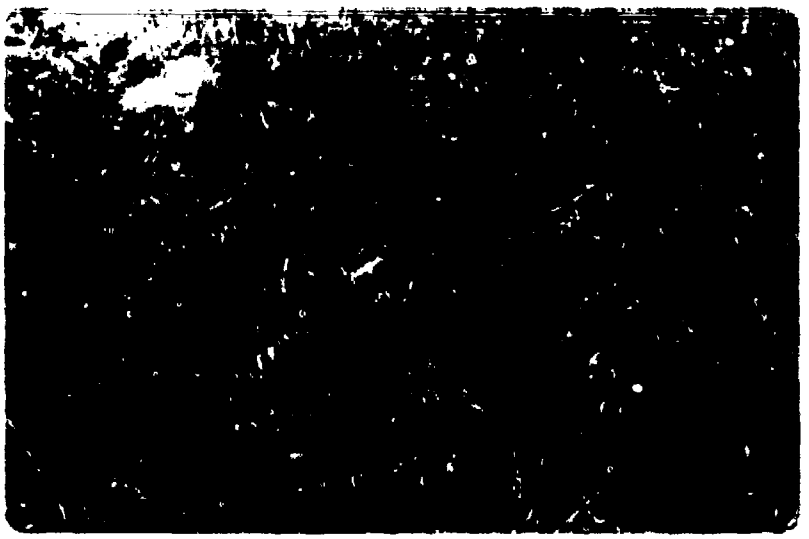

Figure 18. Effect of Test 10, 18 Days After Spraying.

11. Test 11

a. Description

Date of Spray: 29 December 1961 from 1000 to 1300 and again at 1500 to about 1530.

Place: (a) Dinoxol was sprayed north of Route 15 adjacent to an airstrip about four kilometers toward Long Thanh from the site of Test 10 and along roadside segments of Route 15 for several kilometers. (b) Blue code was sprayed near the airstrip mentioned above in the afternoon.

Coordinates of sprayed areas are given for Dinoxol as (and these were obtained from the VN):

YS 140981 to YT 150987 - Airstrip

YT 100020 to YT 105015 - Both sides Route 15.

YS 112998 to YS 114986 - Both sides Route 15.

YS 124970 to YS 128962 - West side Route 15.

YS 204833 to YS 229794 - Both sides Route 15.

Blue code material coordinates for spray were:

YS 134985 to YS 140988

Chemical Sprayed: Dinoxol was sprayed later in the day, after Test 10. The vegetation at the west side of the airstrip was sprayed for almost the full length first; about half was sprayed again. Ground speed in both cases was ten kilometers per hour. This was the last of the Dinoxol and the District Chief, Lt. Ngo, indicated a desire to have certain segments of the roadside of Route 15 sprayed as well. Less than 50 gallons of Dinoxol was sprayed. Along the roadside most of the material was sprayed at ten kilometers per hour and the rest at 20 kilometers.

The blue code material was sprayed at ten kilometers per hour along a single-track road near the airstrip.

The vegetation varied from relatively open grass, brush, and trees to dense for (a) and relatively dense for the most part for (b).

Equipment: The Buffalo Turbine was used for these sprays and was functioned aboard a 2½-ton truck.

Flow Rate: Unknown.

Delivery: The spray was delivered generally downward and outward on the vegetation at the airstrip. Along the roadside a vertical fan was directed to spray an arc reaching from horizontal to about 60 degrees elevation.

Wind: Relatively still with slight air movement, estimated less than five knots.

Weather: Bright and clear.

Observation Dates: Visits on the ground are marked with an asterisk, otherwise observations were by flyovers: 3, 5*, 8, 10, 12, 16*, 19, 22, 24, 26* January.

b. Results

The chemicals caused responses considered to be very good to excellent. The results with Dinoxol at the airstrip demonstrated that trees sprayed at this location were generally capable of responding to this chemical. That they received the spray was evident right after spraying. The subsequent response indicated that a sublethal deposit had been achieved in Test 10 with another growth-regulator chemical.

The blue code chemical caused responses that indicated a relatively rapid desiccation of the foliage to an extent that warranted an aerial release.

The roadside sprays with Dinoxol were rated fair to excellent considering the terrain, the depth to which the spray carried from the road, and the type of vegetation encountered. It should be noted that this material is only a 40 per cent concentration and that at the lower rate of delivery (higher road speed) its effects were still marked. It does appear possible that 95 to 100 per cent concentrations could be delivered at even higher road speeds and still achieve a useful effect. However, this should be tested.

c. Discussion

These tests demonstrated that vegetation was still capable of response to growth-regulator chemicals in areas not far removed from where Test 10 was conducted on the same day. The particles of spray delivered by the Buffalo Turbine are believed to be considerably finer (smaller) than those deposited in the intended area of Test 10. It is also believed that, for any given tree that was sprayed, more complete coverage (not necessarily dose) was achieved with the ground equipment.

The performance of the blue code material was quite impressive from the standpoint of causing the foliage to turn brown. However, the degree of permanence of this effect is unknown. Under conditions more favorable for active growth it may be dissipated by regeneration. Because

there was little evidence of variation in response by different species it appears that this chemical may offer promise for jungle use if it does have the desired permanence, if it does prepare green vegetation for burning and natural conditions allow burning, and if there are not other conditions that would prevent its large-scale use at the rates required. Obviously, more research is required to investigate these problems; however, it was deemed worthy of aerial release tests and two were performed (see Tests 13 and 14).

Figures 19 through 21 show Test 11 operation and results. Dinoxol was sprayed from a Buffalo Turbine mounted on a 2½-ton truck.

Figure 19. Spraying for Test 11. Note spray cloud.

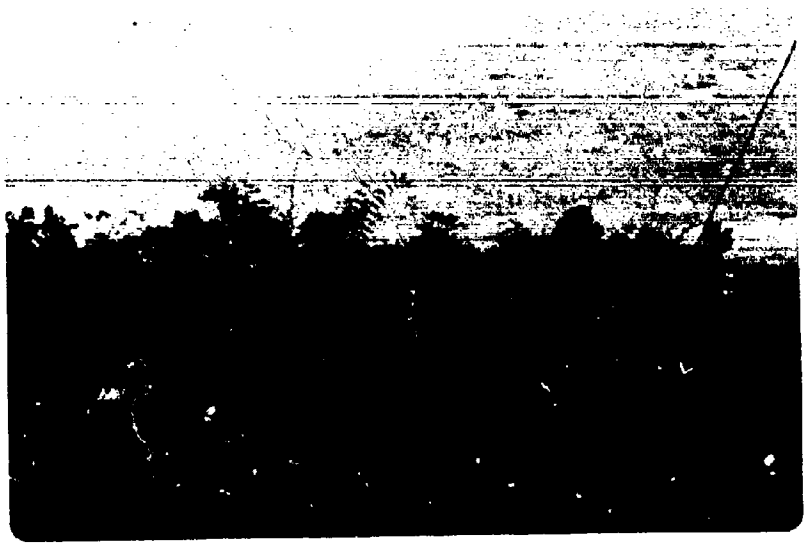

Figure 20. Test 11 Site 18 Days After Spraying. Route 15.

Previous pages were blank, therefore not filmed.

Figure 21. Test 11 Site 18 Days After Spraying. Airstrip.

12. Test 12

a. Flight Description

Date of Spray: 10 January 1962 between 0830 and 0900 hours.

Place: Adjacent to swath attempted in Test 10, on the north side of Route 15.

Chemical Sprayed: Purple code chemical. This was the first release of this material. It was received by and obtained from the VN POL depot the afternoon of 9 January by USAF personnel at the writer's request. Because of its relatively high viscosity and the imminence of USAF tests, it was desirable to make a release with this material from the equipment to be used in the tests. This was the first time out with both the chemical and the equipment. A one-gallon-per-acre rate of deposit was desired and settings calculated or estimated to achieve this in a desirable particle size spectrum were used. Four drums (about 200 gallons) were loaded but not all expended.

Equipment: A C-123 airplane equipped with an Hourglass 1000-gallon spray tank and modified booms was used.

Flow Rate: Attempted 150 gallons per minute with pump pressure at 40 pounds.

Airspeed: 150 miles per hour.

Altitude: 150 feet.

Wind: Light, estimated less than five knots.

Weather: Cloudy.

Observation Dates: 12, 16*, 19, 22, 24 January 1962.

b. Results

Although the spray effect developed to a point where it could be detected from the air, it did not develop much further during the observation period.

The effect of this spray was rated poor.

c. Discussion

It is believed that (a) a sublethal deposit of spray was achieved, (b) active growth was being seriously retarded, or (c) these factors were acting in concert.

* Ground observation.

Upland vegetation not far from this site sprayed with Dinoxol on 29 December (Test 11) was capable of marked response prior to the start of the current test, so that the second condition above was not as suspect as the first. Also, the lack of response in Test 10 on 29 December that resulted from spraying with a very suspect system tended to substantiate the first condition.

Unfortunately, results from Test 12 were not available prior to USAF tests scheduled to start on 13 January, nor was it possible to determine exactly how much of the material had actually been sprayed. The system had not been calibrated for spraying the purple material and in this test there was very little information gained regarding flow rate. By the time it was decided to drain the system to measure the quantity of unsprayed chemical, the tank had been filled preparatory to the USAF missions. Precautions were taken to obtain actual spraying time on the first flights of 13 January, to provide a lead to the flow rate obtained.

The effect of the chemical on the vegetation should have produced responses similar to that of Dinoxol.

13. Test 13

a. Flight Description

Date of Spray: 12 January 1962. The scheduled take-off was made at 0830 but a loose ground wire aborted the mission. After correction the second take-off was made at 1015 and the spray was delivered between 1035 and 1055 hours.

Place: Adjacent to swaths of Tests 10 and 12, on the north side of Route 15.

Chemical Sprayed: Blue code material. This was the first aerial release of this chemical. The deposition rate attempted was about one gallon of material per acre of an aqueous solution that had been prepared the day before by mixing ten pounds of dry powder per gallon of water. This mixture contained about 20 per cent of undissolved solids that had settled overnight and were discarded. At most, 6.5 pounds of active ingredient could have been contained in a gallon, and it is estimated that dissolved active ingredient was closer to five pounds per gallon.

Equipment: H-34 equipped with HIDAL.

Flow Rate: Estimated one-half gallon per acre. Because this system is relatively fixed for the above delivery rate, two passes were made over the same swath.

Airspeed: 50 knots.

Altitude: 50 feet.

Wind: Estimated less than five knots. Flights were in-wind.

Weather: Clear.

Observation Dates: 16*, 19, 22, 24 January, 10* February.

b. Results

The action of this chemical appears to be that of a desiccant. The swath was clearly apparent and very impressive one week after spraying. The effects were still marked one month after spraying, although there was some evidence of regrowth occurring on individual trees and shrubs whose foliage had dried up, shrivelled, and was either still attached or had fallen.

There seemed to be little if any species resistance to the action of this material; that is, if the foliage received the spray, it dried up.

The effect was rated very good to excellent.

* Ground observations.

c. Discussion

To the writer's knowledge, this was the first time this material had been aerially released at this rate and for this purpose.

The relatively rapid and complete action of the chemical was very striking. However, the length of time the effect will remain is unknown. It is doubtful that a high degree of plant killing occurred, even though the foliage was ruined. Judging by the degree of desiccation that occurred, it appears that burning of the foliage may be possible in about ten days, but this has not been tested on jungle vegetation.

It is possible that other rates of application may lead to defoliation per se, or that lower rates could be used to achieve essentially the same degree of effect. These things should be tested further.

In general, it appears that many species may have the reserves to be able to put out a new set of leaves to replace those lost as the result of drought, fire, or insects. Depending on the degree of refoliation, it appears that repeated applications may be warranted if a relatively permanent effect is desired.

Additionally, more information regarding toxicity of this chemical should be obtained prior to its large-scale use at the rate used above. Such information should include the toxicity of products created by decomposition on burning.

Figures 22 and 23 show the results of spraying blue code chemical with the HIDAL and H-34 helicopter.

Figure 22. Effect of Test 13 Ten Days After Spraying.

Figure 23. Effect of Test 13 Twelve Days After Spraying.

14. Test 14

a. Flight Description

Date of Spray: 12 January 1962, about 1115 hours.

Place: VN Navy Yard, Saigon. Unwanted vegetation consisted largely of native grasses and bamboo, ranging from about two to eight feet tall.

Chemical Sprayed: Blue code material. The solution used in Test 13 was also used for this test.

Equipment: H-34 helicopter equipped with HIDAL.

Flow Rate: Two passes were made over the same swath at the fixed flow rate. However, the altitude was less than in Test 13, and for the smaller swath width perhaps somewhat more than one gallon per acre was sprayed.

Airspeed: About 50 knots.

Altitude: About 25 feet to achieve aimability and to avoid spraying desirable vegetation.

Wind: Calm.

Weather: Clear.

Observation Dates: 15*, 19, 22**, 24 January; 1 February.

b. Results

This material caused marked desiccation of the vegetation receiving the spray. One week after spraying it appeared dry enough to burn.

The effects of this test are rated very good to excellent.

c. Discussion

Small-plot tests (Test 15) using this chemical at this site indicated the possibility of rendering this green vegetation fit for burning. It was desired by others to clear the area of vegetation and this test swath was sprayed to see whether subsequent controlled burning would be feasible. Arrangements were made by others to burn the sprayed area ten days after spraying. The area was too large to burn all at once, and it was decided to burn the downwind and major portion first at about 1530 hours.

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* Ground observation.

** Air and ground observation.

It burned successfully, even though soldiers setting the initial fires encountered water half-way to their knees in this tidal area. Winds were slight and variable, but the fire was self-sustaining. A steadier and stronger wind would have aided in accomplishing the burning in less time.

When it was attempted to burn the second portion, the fire failed to catch and spread. It was later in the day and the humidity may have increased somewhat. Also, there was relatively even less wind.

Figures 24 through 26 show the operation and results of Test 14.

Figure 24. Spraying for Test 14.

Figure 25. Test 14, One Week after Spraying.

Figure 26. Results of Test 14 on 1 February. Area was sprayed on 12 January and burned on 22 January.

15. Test 15

a. Description

Date of Spray: 27 December 1961 at 1500 hours.

Place: VN Navy Yard. Vegetation consisted of native grass and bamboo.

Chemical, Rates, Area: The chemical used was cacodylic acid at rates of 2.5, 5, and 10 pounds per acre. One pint of each solution was sprayed on plots seven feet square.

Equipment: A three-gallon hand-sprayer with adjustable nozzle, manufactured by Montgomery Ward.

Weather: Clear with temperature of 70 to 75°F.

Observation Date: 4 January 1962.

b. Results

All plots treated had been desiccated on 4 January 1962. More effect was noted on the 5- and 10-pound-per-acre plots.

c. Discussion

The plot treated at the 10-pound rate had been burned, how or by whom is not known. The plot that received the 5-pound-per-acre rate was tested for burning and burned.

16. Test 16

a. Description

Date of Spray: 4 January 1962 (Chemicals 1 through 8) and 10 January 1962 (remainder) at about 1500 hours.

Place: VN Navy Yard. The vegetation consisted of native grasses and bamboo.

Chemicals, Rates, Area:

Code	Chemical	Solvent*
1	Amino triazole	Water
2	Ammate	Water
3	Endothal	Water
4	Butyne - 1,4-diol	Water
5	Cacodylic acid (80% act.)	Water
6	Ammonium thiocyanate	Water
7	Zinc chloride	Water
8	Simazine	Water
9	Atrazine	Water
10	2,4,5-T propionic	Water
11	Diquat	Water
12	Tributyl phosphate	Fuel oil
13	4534	Fuel oil
14	10778	Fuel oil
15	Pentachlorophenol	Fuel oil
16	Diethylene glycol bis ester of dalapon	Water

All the chemicals were sprayed at three rates (2, 4, and 8 pounds per acre). Cacodylic acid was also sprayed at the rate of one pound per acre. The plot for each rate was estimated to be seven feet square.

The chemicals had been pre-weighed and packaged in small vials. These were then mixed with one pint of either water or fuel oil (see solvent list above) and an estimated one per cent Tween 20 was added to each of the aquecus solutions only.

Equipment: A three-gallon hand-sprayer with adjustable nozzle, manufactured by Montgomery Ward.

Flow Rate: Unknown. The one pint of solution was sprayed evenly over the area until expended.

Weather: Bright and sunny with temperature estimated at 80 to 85°F.

* All water dilutions had Tween 20 added.

Observation Dates: 6*, 8, 15 January.

b. Results

Two days after treatment the plots sprayed with Endothal (8-pound rate) and the plots sprayed with cacodylic acid (4- and 8-pound rates) showed browning of the plant leaves. Four days after treatment these plots showed an increased effect (browning) and the grasses in the plots treated with the cacodylic acid were showing leaf roll, similar to onion leaves.

Eleven days after treatment the plants treated with Endothal and cacodylic acid (all rates) were desiccated. Butyne-1,4-diol showed little effect other than some purple coloration on the leaves at the higher rate; plants treated with ammonium thiocyanate were showing a light green with some purple coloration. Zinc chloride appeared to burn rather than desiccate the leaves at the higher rate. Simazine showed very little effect at any rate. Amino triazole showed good desiccation of the plants and ammate showed a fair amount.

Chemicals 9, 10, and 16 were observed five days after treatment, at which time a small effect could be noted on a few of the plants such as a blackening of the plants for 16 or a light green color on 9 and 10.

Chemicals 11, 12, 13, 14, and 15 showed very good desiccation five days after treatment.

c. Discussion

The effects from the majority of the chemicals were excellent considering the type of vegetation sprayed.

Color slides were made showing effects of chemical and rates.

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* Ground observation.

17. Test 17

a. Test Description

Date of Spray: 19 January 1962 at about 0830 hours.

Place: ARVN Headquarters. The vegetation consisted of native grasses, bamboo, banana, and deciduous trees.

Chemical, Rate, Area: The chemical used was a commercial product "Diquat" (undiluted). The rate and area were not determined, as emphasis was put on individual trees and grass areas.

Equipment: A three-gallon hand sprayer with adjustable nozzle, manufactured by Montgomery Ward.

Flow Rate: Unknown.

Weather: Clear, temperature 78°F, dew present on plants.

Observation Dates: 22, 23 January; 12 February 1962.

b. Results

Excellent results were noted on all types of vegetation sprayed.

c. Discussion

The chemical performed very well, desiccating all the vegetation sprayed within four days after treatment.

Figures 27 through 30 show the results of Test 17 three days after spraying.

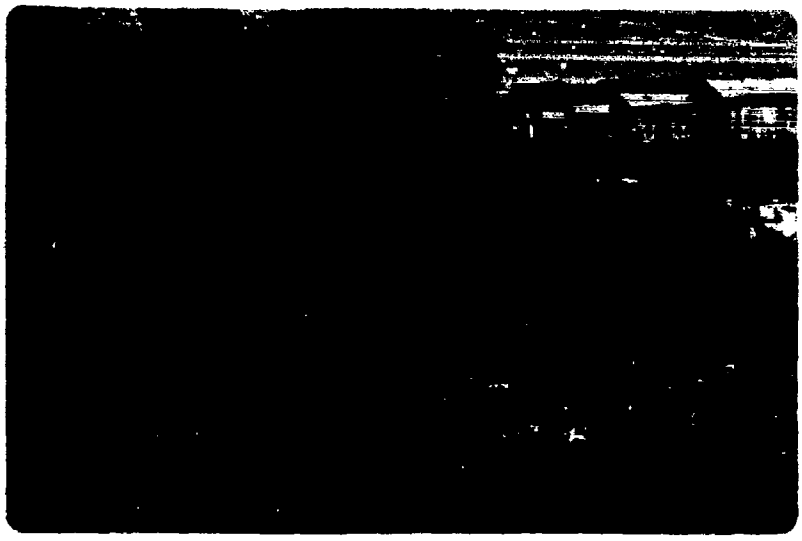

Figure 27. Test 17. Effect of Diquat Three Days After Spraying.

Figure 28. Test 17. Effect of Diquat Three Days After Spraying.

Figure 29. Test 17. Effect of Diquat Three Days After Spraying.

Figure 30. Test 17. Effect of Diquat Three Days After Spraying.

18. Test 18

a. Description

Date of Spray: 3 February 1962, at about 1700 hours.

Place: A small hill on the western outskirts of Bien Hoa chosen by Colonel Thang, the CO of the Division. He planned to prepare a gun emplacement on the hill and wanted to reduce the 2- to 10-foot vegetation, which consisted of grasses, shrubs, briars, and trees.

Chemical Sprayed Blue code material in aqueous solution of about 80 pounds of powder added to 100 gallons of water. Two hundred additional pounds of chemical were on location but were not expended at this time. It is not known to the writer whether or how much additional chemical may have been sprayed later that affected the results.

Equipment: Buffalo Turbine chained securely in the bed of a 2½-ton truck.

Flow Rate: The area covered with the spray was estimated to be about five to seven acres. The spray was delivered until expended.

Wind: Estimated at less than five knots.

Weather: Few scattered clouds.

Observation Date: 14 February (ground).

b. Results

The green foliage and grasses had become dry and shrivelled in eleven days. The effects of the chemical were rated very good to excellent.

c. Discussion

The results of this test, combined with those of previous tests with the blue code material, are indicative of considerable promise. desirable features are that it is relatively rapid and complete in its desiccating action and appears to be effective on almost all species encountered in these tests. It offers promise of being able to burn formerly green foliage in about ten days after spraying, provided that other natural conditions, such as a high relative humidity, do not interfere.

Undesirable features are that it has a corrosive property that limits its use to noncorrosive systems. It is apparently less toxic than DDT to animals, but more information is needed to demonstrate its safety for those who may have to handle it. Its residual effect and fate, either in soil or decomposition in burning, should be determined.

Figures 31 and 32 show the results of this test 11 days after spraying.

Figure 31. Effect of Test 18 Eleven Days After Spraying.

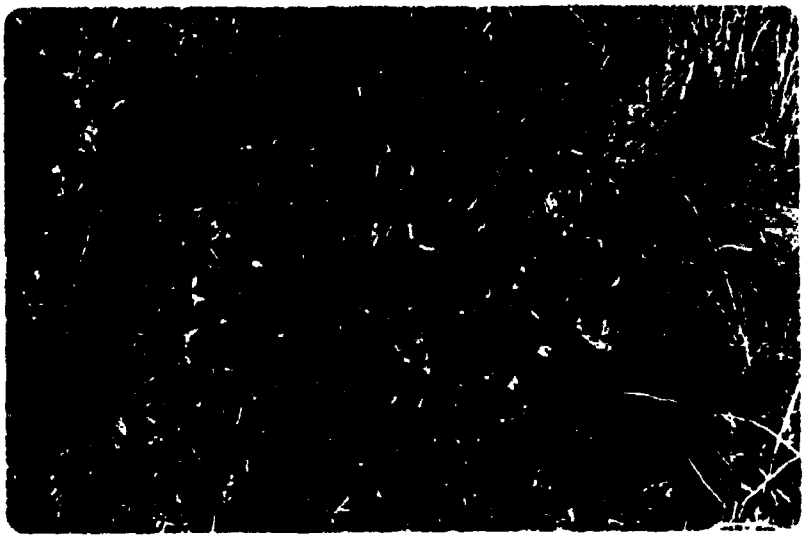

Figure 32. Effect of Test 18 Eleven Days After Spraying.

B. USAF OPERATIONAL TESTING

When the writer returned to the US in mid-November 1961, he attended a meeting at ARPA and requested that he be allowed to return to Vietnam if and when it was decided to scale up the vegetational spray effort, so that he could provide technical guidance. At that time it was considered doubtful that the writer could be returned unless there was some unfinished or more research to be accomplished. The writer indicated that there certainly was research testing yet to be done with candidate chemicals that were available only in small quantities. At that time the decision for his return to Vietnam was held in abeyance.

There followed a relatively intense round of briefings that were requested of the writer during the next few weeks.

By 4 December a decision had been made that the writer should return to Vietnam and oral instructions were given to him on that date (Section XIX of the Supplement). However, on his return to Vietnam, implementing documents were not available to the writer and with the passage of time it became more and more evident they would not be. Thus, he was in an untenable position of having a tremendous but unrecognized responsibility and no authority. There was little he could accomplish under these circumstances to aid in the accomplishment of the scaled-up mission. Targets were selected, leaflets were prepared for airdrop, meetings, briefings, and discussions were held pertinent to the mission without his knowledge, contribution, or guidance. He was unable to get a C-123 made available for check-out tests in December despite repeated requests. He even suggested that equipment be calibrated elsewhere if it could not be done in Vietnam. The planes were in the Philippines, the purple code chemical was on the high seas, a supply of pink and green code chemical was in Vietnam. The pink material was of nearly the same viscosity as the purple and he suggested sending this to the Philippines if a plane could not come to Vietnam. Permission to calibrate the equipment in the Philippines could not be obtained. Test 10 is mentioned as having as an objective the indoctrination of the spray pilots using the C-47 equipment with more viscous material (pink). It took almost twice as long to disseminate the material in that system as had been calculated.

On 9 January the purple material arrived, and on 10 January a rough functional test spray was made, using four drums of this material in a C-123. The plane was obtained as the result of a direct personal request to General Anthis USAF, and the request was immediately granted. By this time the spray schedule had been set to start 13 January for Route 15 targets and time was extremely short. All of the material was not released,

but it is not known how much was released. Conditions for the spray release on 10 January were 150-foot altitude (high enough to allow the spray from the two booms to join under the fuselage prior to deposition), 150 mph, 40 pounds pump pressure, an estimated flow rate of 150 gallons per minute (although the 84 nozzles of the D16/45 T-jet are rated to deliver 1.5 gallons* of water per minute at 40 pounds pressure). The estimated mass median diameter of particles was 150 to 200 microns. The effective swath width was planned to be 500 feet.

These conditions were planned by Captain Dowell (who has had years of experience in spraying for other purposes) to achieve a deposition of one gallon of material per acre (5 pounds each of 2,4-D and of 2,4,5-T).

The spray looked good as long as it was visible, and under the prevailing conditions appeared to be well placed, adjacent to and downwind from the C-47 swath of 29 December (Test 10).

As indicated above, time was too short for biological responses to occur prior to scheduled sprayings by USAF along Route 15. The vital piece of missing information was amount of material released, if critical adjustments to the equipment were to be accomplished prior to 13 January. It was recognized that this information could only be obtained on "operational" flights and preparations were made to obtain it on 13 January. I requested the spray pilots to allow me to ride the spray plane on 13 January, and they arranged this.

On the first "operational" flight the conditions were the same as for the 10 January flight above except that 960 gallons were sprayed in 490 seconds (actual spraying time) at a pump pressure of 45 pounds. From this information it was calculated that even with the pump pressure increased by 5 pounds, the flow rate was about 0.8 gallon per acre.** On the second load two adjustments were made. Flight centers were reduced from a 500- to a 400-foot spacing (this calls for an eyeball estimation by the pilot) and the pump pressure was raised to 48 or 49 pounds. The second load of 960 gallons was expended in 450 seconds of spraying time from similar

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* Perhaps this figure should have been 1.79 (for D16/45 T-jets) instead of 1.5, which appears as 1.53 in the manufacturer's literature for D14/45 T-jet nozzles.

** 150 mph = 220 ft/sec; $\frac{220 \times 500 \text{ (swath width)}}{43560 \text{ (sq. ft. per acre)}} = 2.5$ acres/sec.

$\frac{960 \text{ gallons}}{490 \text{ seconds}} = 1.96$ gal/sec; $\frac{1.96}{2.5} = 0.78$ gallon per acre.

equipment in a different C-123 but with the same air crew. Calculations from these adjustments indicated that a flow rate of about 1.05 gallons per acre* was achieved.

The first load was sprayed between 0805 and 0825 hours, the second from about 0940 to 0955. It was observed on the second run that spray released on the last few swaths was rising. The commander of an observation plane accompanying the spray plane and flying parallel to but above and to one side behind it, confirmed the rising of the spray by reporting that it was being deposited on the windshield. I recommended to the pilots that future operations be conducted prior to 0900 to avoid the loss of inversion conditions, which interfered with spray deposition and caused dissipation of the spray. The pilots, of course, for years had recognized the importance of inversion conditions in connection with their own spray operations but by adding my recommendation to theirs it was hoped that the need for spraying under inversion conditions would be recognized.

Calibration of the C-123 equipment would have been very helpful in giving a clue to per cent deposition or recovery on the ground but, without it, it was felt that under the circumstances all possible had been done.

In subsequent ground observations of the areas sprayed 29 December (Test 10), 10 January, and 13 January, it was apparent that in all of these upland areas that had been sprayed by aircraft, the effect was not developing as it should. It was indicated that the spray had not gotten down in sufficient quantity, had not penetrated the foliage sufficiently, or the vegetation was not in a growth state that could respond. On 26 January evidence was obtained that vegetative growth was practically at a standstill because of the dry season (Section XVI of the Supplement) - a condition that is capable of delaying marked vegetational response.

A memorandum was prepared 28 January (dated 29 January) for the Chief of MAG R&D Division (Section XV of the Supplement) which detailed the writer's appraisal of the situation and was turned in late in the afternoon of 29 January after the writer had been able to find and talk to a VN official who had some knowledge of VN vegetational growth as related to the dry season. Confirmation was thus obtained.

The morning of January 30, MAAG G-3 was informed of the recommendation to hold spray operations in abeyance in those areas where the dry season was seriously curtailing vegetative growth. At that time a request by them for permission to spray other roadside targets had already entered channels.

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* $\frac{960 \text{ gallons}}{450 \text{ seconds}} = 2.13$ gal/sec; $\frac{220 \times 400}{43560} = 2.02$ acres/sec.

$\frac{2.13}{2.02} = 1.05$ gallons per acre.

It is not known whether an effort was made from that point on to restrict the request to mangrove areas or other sites where soil moisture was not limiting or to stop the request, but in the middle of February other targets were sprayed.

In an effort to provide useful information to user elements, "Vegetation Spray Information" (Section XVII of the Supplement) was compiled by the writer in Vietnam during late January and the first week in February. It was requested that this information be stenciled and circulated to those having a need to know.

Figures 33 through 35 show the results of spraying purple code chemical with a modified Hourglass and C-123 aircraft.

Figure 33. USAF Test 17 Days after Spraying.

Figure 34. USAF Test 26 Days after Spraying.

Figure 35. USAF Test 26 Days after Spraying. Note mangrove (central area showing gray wood) completely bare of leaves.